IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application of Daniel R. Wright et al. Art Unit 1616
Serial No. 10/829,572
Filed April 22, 2004
Confirmation No. 6729
For HERBICIDAL COMPOSITIONS CONTAINING GLYPHOSATE AND A PYRIDINE ANALOG
Examiner Courtney A. Brown

Declaration of Daniel R. Wright under 35 C.F.R. §1.132

I, Daniel R. Wright, declare and state as follows:

A. I am a Project Leader for Monsanto Technology LLC, and am a co-inventor of the herbicidal glyphosate and pyridine analog compositions that represent the subject matter of the present application. I received a B.S. in Chemistry from Henderson State University in 1978, and a Ph.D. in Physical Organic Chemistry from the University of Arkansas in 1983.

B. I have been asked to:

1. Review the Office Action dated July 9, 2010 issued in connection with the present application;

2. Review the claims of the present application;

3. Analyze the experimental examples disclosed in the present application in order to ascertain whether combinations of glyphosate and a pyridine analog falling within the scope of the present claims overcome herbicide antagonism between glyphosate and pyridine analog herbicides; and

4. Analyze the cited reference Hacker (US 6,677,276 B1) for evidence of herbicidal synergy associated with a combination of glyphosate and a pyridine analog herbicide

DRW

falling within the scope of the claims pending in the present application.

5. In summary, it is my opinion that (i) the present application demonstrates that glyphosate and pyridine analog compositions falling within the scope of the pending claims are not antagonistic and may exhibit synergy on grasses and (ii) Hacker would not have suggested that the combination of glyphosate and a pyridine analog herbicide as presently claimed is not antagonistic or provides synergistic control of grass plant species.

C. It was well known to those skilled in the art as of the 22 April 2003 priority date of the present application that pyridine analog herbicides can be antagonistic to (i.e., can reduce the herbicidal activity of) glyphosate or an herbicidal derivative thereof on grass plant species.[1]

D. I, along with the other co-inventors, have surprisingly discovered that formulating glyphosate in weight percent acid equivalent ("a.e.") excess over pyridine analog herbicide content overcomes the herbicidal antagonism problem in connection with grass plant species and, in some instances, provides enhanced early symptoms of herbicidal efficacy for the combination of herbicides as compared to what would be expected from the additive effect of the herbicides individually applied. More particularly:

1. The combination of claim 29 of (a) a glyphosate salt, (b) a pyridine analog herbicide or a salt or ester thereof, and

[1] See the specification of the application as filed at page 19, lines 10-12 (corresponding to the last sentence of paragraph [0070] of United States publication no. US 2005/0026781 A1). See also attached Exhibit 2, discussed infra in section F(1), wherein it is disclosed that phenoxy and auxin-type herbicides may reduce glyphosate efficacy and Exhibit 3 disclosing that each the claimed herbicides triclopyr, clopyralid, fluroxypyr and picloram are auxin herbicides.

DKW

(c) at least one surfactant, wherein the glyphosate (acid equivalent basis) and the pyridine analog (acid equivalent basis) are present in a weight ratio of at least 7.6:1 overcomes the antagonism problem; and

2. The combination of claim 46 of (a) at least one glyphosate salt predominantly in the form of potassium glyphosate, monoethanolamine glyphosate, or a mixture thereof, and (b) a pyridine analog herbicide selected from the group consisting of triclopyr, clopyralid, fluroxypyr, dithiopyr, thiazopyr and picloram, or a salt or ester thereof, wherein (i) the glyphosate salt is present in a concentration less than 315 grams acid equivalent per liter and the glyphosate salt (acid equivalent basis) and the pyridine analog (acid equivalent basis) are present in a weight ratio of at least 7:1, (ii) the glyphosate salt is present in a concentration less than 320 grams acid equivalent per liter and the glyphosate salt (acid equivalent basis) and the pyridine analog (acid equivalent basis) are present in a weight ratio of at least 8:1, (iii) the glyphosate salt is present in a concentration less than 324 grams acid equivalent per liter and the glyphosate salt (acid equivalent basis) and the pyridine analog (acid equivalent basis) are present in a weight ratio of at least 9:1, or (iv) the glyphosate salt is present in a concentration less than 326 grams acid equivalent per liter and the glyphosate salt (acid equivalent basis) and the pyridine analog (acid equivalent basis) are present in a weight ratio of at least 10:1 overcomes the antagonism problem.

E. I was asked to analyze the experimental results presented in the present application, published as US 2005/0026781 A1, to ascertain whether combinations of glyphosate and a

DHW

pyridine analog, where glyphosate is in weight percent a.e. excess, overcome herbicide antagonism between glyphosate and pyridine analog herbicides. In summary, the experimental results show that glyphosate and pyridine analog herbicides are not antagonistic to plant control when co-formulated in weight percent excess glyphosate, and the highest plant control is achieved when the weight ratio of glyphosate to pyridine analog exceeds 6.7:1.

1. Submitted herewith is an analysis of experimental results presented in Tables 3.2.A and 4.4.1 of the present application that show an additive effect (i.e., no antagonism) or synergistic effect for some combinations of glyphosate and a pyridine analog herbicide. An additive effect is shown where the actual efficacy for an herbicide combination is equal to the expected efficacy as calculated by the Colby method from applications of the herbicides individually and a synergistic effect is shown where the actual efficacy is greater than the expected efficacy.

2. (a) To provide a consistent comparative basis, the analysis was restricted to compositions F4C, F0C, RU1 and BBG, each having approximately equal application rates of glyphosate and pyridine analog, both individually and in combination. Formulation F4C, diluted at a rate of 6 ounces per gallon, had a diluted application concentration of 0.62 weight percent a.e. (wt% a.e.) glyphosate and 0.14 wt% a.e. triclopyr. Formulation F0C, comprising glyphosate and no co-herbicide, was diluted at a rate of 6 ounces per gallon, and had a diluted application concentration of 0.62 wt% a.e. glyphosate. Formulation RU1, comprising glyphosate and no co-herbicide, was diluted at a rate of 6 ounces per gallon, and had a diluted application concentration of 0.93

DKW

wt% a.e. glyphosate. Formulation BBG, comprising triclopyr and no co-herbicide, was diluted at a rate of 4 ounces per gallon, and had a diluted application concentration of 0.18 wt% a.e. triclopyr.

(b) The remaining formulations comprising a combination of glyphosate and triclopyr did not contain a diluted triclopyr concentration approaching that of formulation BBG (i.e., 0.18 wt% a.e triclopyr) such that an analysis of Colby synergy could not be done. More particularly, formulations F3X, F3M and F3C contained 0.093 wt% a.e. triclopyr, formulations F2X, F2M and F2C contained 0.047 wt% a.e. triclopyr, and formulations F1X, F1M and F1C contained 0.023 wt% a.e. triclopyr.

3. A summary of the experimental examples demonstrating surprising results of additive or synergistic efficacy is presented in the table below where "Table" refers to an example table presented in the present application, "wt% a.e. gly" and "wt% a.e. tric." refer to the glyphosate and triclopyr concentrations in the application mixtures, and "Expected %Control" was calculated by the method of Colby from individual applications of glyphosate and triclopyr.[2]

[2] See Exhibit 1: Colby, S.R., "Calculating synergistic and antagonistic response of herbicide combinations," Weeds, 15, 20-22, 1967. The Colby method is widely accepted by those skilled in the art as a method for determining whether herbicide combinations show antagonism or synergy. Under the Colby method, the expected efficacy for a herbicide combination is calculated from the efficacy of those herbicides applied individually according to the equation:

$$E = X + Y - XY/100$$

where E is the expected herbicidal efficacy, X is the percent inhibition of growth by herbicide A (i.e., glyphosate) and Y is the percent inhibition of growth by herbicide B (i.e., triclopyr). For Maple from table 3.2A of the present application, an expected efficacy (E) of 56.8 is calculated from the individual efficacies as follows: (10 + 52) - (10)(52)/100 = 56.8.

DSW

Table	Form.	wt% a.e. gly	wt% a.e. tric.	Plant species: actual %Control (DAT)	Expected %Control for gly.-tric. comb.	Result of comparison of actual versus expected control
3.2A	F4C	0.62	0.14	Maple: 58 (5)	-----	
	F0C	0.62	----	Maple: 10 (5)	56.8	No antagonism
	BBG	----	0.18	Maple: 52 (5)		
3.2B	F4C	0.62	0.14	Maple: 100 (21)	-----	
	F0C	0.62	----	Maple: 94 (21)	100	No conclusion
	BBG	----	0.18	Maple: 100 (21)		
3.2A	F4C	0.62	0.14	Oak: 45 (5)	-----	
	F0C	0.62	----	Oak: 3 (5)	49	No antagonism
	BBG	----	0.18	Oak: 48 (5)		
3.2B	F4C	0.62	0.14	Oak: 94 (21)	-----	
	F0C	0.62	----	Oak: 73 (21)	100	Essentially no antagonism
	BBG	----	0.18	Oak: 100 (21)		
4.4.1	F4C	0.62	0.14	Poison Ivy: 95 (5)	----	
	RU1	0.94	----	Poison Ivy: 80 (5)	93	No antagonism
	BBG	----	0.18	Poison Ivy: 86 (5)		
4.4.1	F4C	0.62	0.14	Poison Ivy: 100 (16)	----	
	RU1	0.94	----	Poison Ivy: 95 (16)	100	No conclusion
	BBG	----	0.18	Poison Ivy: 100 (16)		
4.4.1	F4C	0.62	0.14	Fesc/Blue: 90 (5)	----	
	RU1	0.94	----	Fesc/Blue: 50 (5)	75	Synergy
	BBG	----	0.18	Fesc/Blue: 50 (5)		
4.4.1	F4C	0.62	0.14	Fesc/Blue: 100 (16)	----	
	RU1	0.94	----	Fesc/Blue: 95 (16)	98	No conclusion
	BBG	----	0.18	Fesc/Blue: 65 (16)		
4.4.1	F4C	0.62	0.14	Golden Rod: 90 (5)	----	
	RU1	0.94	----	Golden Rod: 50 (5)	70	Synergy
	BBG	----	0.18	Golden Rod: 40 (5)		
4.4.1	F4C	0.62	0.14	Golden Rod: 98 (16)	----	
	RU1	0.94	----	Golden Rod: 95 (16)	98	No conclusion
	BBG	----	0.18	Golden Rod: 65 (16)		
4.4.1	F4C	0.62	0.14	Poison Ivy: 100 (14)	----	
	RU1	0.94	----	Poison Ivy: 80 (14)	94	Slight Synergy

DKW

	BBG	----	0.18	Poison Ivy: 70 (14)		

4. Comparison of expected %control for glyphosate + triclopyr at 5 days after treatment ("DAT") calculated from the efficacy for separate glyphosate and triclopyr application versus actual %control for formulation F4C (containing glyphosate and triclopyr) indicates either lack of antagonism (where expected and actual control are approximately equal) or synergy (where actual control exceeds expected control) for the trials summarized in the table.

5. Comparison of expected %control for glyphosate + triclopyr at 21 or 16 DAT calculated from the efficacy for separate glyphosate and triclopyr application versus actual %control for formulation F4C (containing glyphosate and triclopyr) indicates an essential lack of antagonism on oak at 21 DAT and slight synergy on poison ivy at 14 DAT. No conclusion could be reached for the remaining 21 and 16 DAT trials because the actual and expected efficacies were about 100.

6. Further evaluation of Table 3.2B for oak percent control at 21 DAT for varying ratios of glyphosate to pyridine analog (triclopyr) are summarized in the table below.

Treatment (formulation)	Glyphosate:Triclopyr	% Oak control 21 DAT
4 (F0X)	No triclopyr	90
1 (F3X)	6.7:1	97.5
2 (F2X)	13.3:1	100
3 (F1X)	27:1	100
8 (F0M)	No triclopyr	81.5

DSW

5 (F3M)	6.7:1	90
6 (F2M)	13.3:1	95
7 (F1M)	27:1	99
13 (F0C)	No triclopyr	72.5
9 (F4C)	4.4:1	94
10 (F3C)	6.7:1	95
11 (F2X)	13.3:1	99
12 (F1X)	27:1	99

The data show the pyridine analog herbicide did not reduce long-term glyphosate control of oak plants (i.e., 21 DAT) and the highest percent control is achieved at ratios of glyphosate to pyridine analog in excess of 6.7:1.

F. I was also asked to evaluate the cited reference US 6,677,276 B1 (Hacker), including analysis of the examples disclosed therein, for evidence of synergy for the presently claimed combination of glyphosate and a pyridine analog herbicide. In summary, Hacker asserts synergy for a large number of herbicide combinations, but presents only four experimental trials in support thereof, each directed to glufosinate in combination with a co-herbicide. Analysis of the data present in Hacker Table 5 shows that the combination of glufosinate and the pyridine analog herbicide clopyralid, where glufosinate is in weight percent excess, is antagonistic on control of *Chenopodium album* thereby expressly contradicting Hacker's assertion of synergy. As explained in detail below, it is my opinion that Hacker would not have suggested to one skilled in the

DBW

art that, as applied to grass plant species, (i) the presently claimed combination of glyphosate and pyridine analog herbicides are synergistic or (ii) formulating glyphosate in weight percent excess over a pyridine analog herbicide can overcome antagonism between glyphosate and a pyridine analog herbicide.

1. **(a)** It was well known to those skilled in the art as of the 22 April 2003 priority date of the present application that the herbicidal efficacy associated with combinations of herbicide species from two herbicide classes is unpredictable and biological incompatibility frequently occurs.

(b) Hacker acknowledges that unpredictability at column 1:45-49 stating that "phenomena of physical and biological incompatibility, for example lacking stability of a coformulation, decomposition of an active ingredient or antagonism of the active ingredients, occur not infrequently when using several active ingredients in combination."

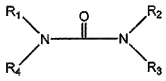
(c) As shown in attached Exhibit 2, it was further known to those skilled in the art that certain herbicides such as auxin herbicides, substituted urea herbicides and phenoxy herbicides are antagonistic to glyphosate and can reduce glyphosate efficacy in herbicide co-formulation compositions.[3]

[3] As disclosed in Exhibit 2, HERBICIDE HANDBOOK, Weed Science Society of America, Eighth Edition (2002), pages 231-234 at page 232, second column under the sub-heading "Incompatibilities": "**Tank mixing [glyphosate] with residual herbicides such as substituted ureas and triazines or with POST herbicides such as paraquat, dalapon, MSMA, phenoxy, or other auxin-type herbicides may reduce glyphosate efficacy.**" (emphasis added)

DRW

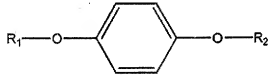
(i) Auxin herbicides covered by the Exhibit 2 disclosure that may be antagonistic to glyphosate include the presently claimed pyridine analog herbicides triclopyr, clopyralid, fluroxypyr and picloram. In support thereof, as described in attached Exhibit 3, each of triclopyr, clopyralid, fluroxypyr and picloram are auxin herbicides.

(ii) Substituted urea herbicides covered by the Exhibit 2 disclosure that may be antagonistic to glyphosate are based on a urea moiety of the following general structure:



and include the herbicides dimefuron and ethametsulfuron-methyl. In support thereof, as depicted in Exhibit 3, dimefuron and ethamethsulfuron-methyl are each based on an urea moiety. Hacker at columns 9:65, 9:66-67, and column 11:60-61 suggests that combinations of glyphosate (referenced at A2) and dimefuron (referenced as B1.6) and glyphosate and ethametsulfuron-methyl (referenced as B2.4) are synergistic but provides no experimental evidence in support.

(iii) Phenoxy herbicides covered by the Exhibit 2 disclosure that may be antagonistic to glyphosate are based on a phenoxy moiety of the following general structure:



and include the herbicides quizalofop, fenoxaprop, fluazifop, haloxyfop and propaquizafop. In support

DBH

thereof, as depicted in Exhibit 3, quizalofop, fenoxaprop, fluazifop, haloxyfop and propaquizafop are each based on a phenoxy moiety. Hacker at columns 7:50 to 8:14 and column 11:60-61 suggests that combinations of glyphosate (referenced at A2) and quizalofop (referenced as B3.1), fenoxaprop (referenced as B3.2), fluazifop (referenced as B3.3), haloxyfop (referenced as B3.4) and propaquizafop (referenced as B3.5) are synergistic but provides no experimental evidence in support.

2. (a) Hacker broadly discloses synergy for the combination of 4 different classes of Group A herbicides and 6 different classes of Group B herbicides[4] encompassing over 40 herbicide species and an innumerable number of potential combinations of herbicide species.

(b) Each of the 10 herbicide classes has a unique mode of action in plants. For instance, glyphosate is an enolpyruvate shikimate-3-phosphate synthase inhibitor; glufosinate is a glutamine synthetase inhibitor; and clopyralid is a synthetic auxin. In view of common general knowledge in the art as of the present priority date, and as admitted by Hacker, one skilled in the art would understand that the co-activity between co-formulated herbicides from differing classes is unpredictable.

---

[4] Group A herbicides include glufosinate (a glutamine synthetase inhibitor); glyphosate (an enolpyruvyl shikimate-3-phosphate (EPSP) synthase inhibitor); imidazolinones (acetolactate synthase (ALS) or acetoydroxy acid synthase (AHAS) inhibitors); and pyraflufen, carfentrazone, oxadiargyl and sulfentrazone (protoporphyrinogen (PPO) inhibitors). Group B herbicides include metazochlor, trifluralin, naproamide and carbetamide (mitosis inhibitors); clomazone, (carotenoid biosynthesis inhibitors); dimefuron and pyridate (photosystem II inhibitors); clopyralid (synthetic auxins); ethametsulfuron-methyl (acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) inhibitors); quizalofop, fenoxaprop, fluazifop, haloxyfop, propaquizafop, sethoxydim, cycloxydim and clethodim (acetyl CoA carboxylase (ACCase) inhibitors. See Hacker at columns 4-8.

DAW

(c) The herbicide combinations of the general Hacker disclosure and asserted therein to be synergistic include (i) glyphosate in combination with (ii) dimefuron(a photosystem II inhibitor), clopyralid (an auxin), ethametsulfuron-methyl (an acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) inhibitor), or quizalofop, fenoxaprop, fluazifop, haloxyfop or propaquizafop (acetyl CoA carboxylase (ACCase) inhibitors). Each of the non-glyphosate co-herbicides in those combinations are suggested by the HERBICIDE HANDBOOK (Exhibit 2) as reducing glyphosate activity.

3. (a) Hacker does not present any experimental evidence to support alleged synergy for glyphosate compositions in combination with any coherbicide, much less the selection of glyphosate in combination with a pyridine analog herbicide as is presently claimed.

(b) Hacker does provide experimental evidence in Table 5 at column 20 purporting to show synergy for the combination of glufosinate (a phosphoherbicide, referenced as Active Ingredient A1.2) and clopyralid (a pyridine analog herbicide falling within the scope of the present claims, referenced as Active Ingredient B2.2) at a weight ratio of glufosinate to clopyralid of 2.3:1[5]. Analysis of the results however, as explained below, show that (i) no conclusion for the asserted synergistic herbicidal effect on *Cirsium arvense* (Canada thistle) broadleaf plants can be made and (ii) the herbicide combination is <u>antagonistic</u> on *Chenopodium album* (Lambsquarters) broadleaf plants.

[5] Calculated as follows: (230 grams active substance (a.i.) glufosinate-ammonium)(0.91 a.e./a.i) / (90 grams clopyralid a.e.) = 2.3:1.

DAW

(i) *Cirsium arvense*

On *Cirsium arvense*, E^C (expected synergy by the Colby method) was calculated to be 98% and the actual control was 100%. One skilled in the art would understand that synergy cannot be shown where essentially complete control is expected because a showing of synergy would require actual control to be greater than 100%, which is impossible. Therefore the *Cirsium arvense* results are inconclusive and would not have provided any synergy guidance to one skilled in the art for the combination of glufosinate and clopyralid, much less the presently claimed combination of glyphosate and clopyralid.

(ii) *Chenopodium album*

Hacker reports only an estimated E^A for the combination of glufosinate and clopyralid at the weight ratio range of 2.3:1. E^A is defined by Hacker at column 18:61 as the "total of the herbicidal actions of the individual applications," but it is not clear from the specification how E^A is calculated. Apparently, E^A represents the sum of the efficacies resulting from individual application of the herbicides.[6] Accordingly, the E^A of 80 reported at column 20:25 for glyphosate and clopyralid must be incorrect. Instead, that E^A would be 140% calculated as the sum of glufosinate-ammonium control of 90% (column 20:21) and clopyralid control of 50% (column 20:24). An E^A of 140% is meaningless, as well as impossible, and could not have provided one skilled in the art with any estimation or suggestion of synergy whatsoever. A Colby expected

[6] See Hacker Table 5 *Cirsium arvense* data where E^A is shown to be 85 (column 20:23) which must be the sum of (B2.4) ethametsulfuron-methyl control (reported at column 20:22 as 0%) and (A1.2) glufosinate-ammonium control (reported at column 20:21 as 85%).

DKW

efficacy (E^C) of 95% was calculated from control percentages for glufosinate and clopyralid applied individually.[7] Comparison of the actual *Chenopodium album* control of 85% (column 20:24) versus an expected E^C of 95% teaches that the combination of glufosinate and clopyralid at a weight ratio of 2.3:1 is **antagonistic**.

4. (a) Hacker further asserts that a weight ratio range of glyphosate to the pyridine analog herbicide clopyralid is very particularly preferably from 60:1 to 1:20. It is submitted that the disclosed range provides no guidance, suggestion or starting point to one skilled in the art for the selection of the narrowly claimed weight ratio range of glyphosate to pyridine analog herbicide of, most broadly, 7.6:1 to 20:1.

(b) Hacker teaches that all of the co-herbicide compositions broadly disclosed therein and having a co-herbicide in weight percent excess over glyphosate (e.g., a weight ratio of glyphosate to co-herbicide of 1:2) have synergistic herbicidal efficacy. In accordance with the present invention, it has been discovered that the herbicidal effect for the combination of glyphosate and a pyridine analog, where the pyridine analog is in weight percent excess over glyphosate, is instead antagonistic. Hacker therefore would not have suggested the presently claimed ratio in that respect.

(c) Hacker therefore provides no basis or benchmark from which one skilled in the art would have derived the narrowly claimed range for the purpose of overcoming

[7] Colby synergy (E^C) = 50 + 90 - (50)(90)/100 = 95%.

DKW

herbicidal antagonism associated with the combination of glyphosate and pyridine analog herbicides.

H. One skilled in the art upon reading Hacker in view of common general knowledge known to those skilled in the art as of the present priority date would not have been taught, nor would Hacker have suggested, that glyphosate and pyridine analog (i.e., auxin) co-herbicide combinations are synergistic. Starting from Hacker, those skilled in the art, would not have had a reasonable expectation of success in deriving the present claims therefrom.

1. In particular:

(a) The prior art teaches that glyphosate and the pyridine analog herbicides may be incompatible and antagonistic in combination;

(b) Hacker states that biological incompatibility and lack of stability of a formulation of co-herbicides occurs "not infrequently;"

(c) Because of the unpredictability in the art and in view of the common general knowledge in the art regarding antagonism, experimental evidence is typically required to support an allegation of synergy resulting from the combination of herbicides from two or more classes of herbicides;

(d) Hacker offers no such evidence in support of the broad assertion that glyphosate and pyridine analog herbicides interact synergistically. Hacker provides a very broad disclosure of co-herbicide combinations but only offers (i) experimental evidence for combinations of glufosinate and certain co-herbicides that are not pyridine analog herbicides and (ii)

DHW

experimental evidence demonstrating **antagonism** between glufosinate (a phosphoherbicide) and clopyralid (a pyridine analog herbicide falling within the scope of the present claims). Hacker's examples therefore expressly contradict his broad assertions of synergy for co-herbicide combinations comprising clopyralid, and teaches away from the present claims in that regard;

(e) Hacker provides a broad disclosure of co-herbicide combinations covering an innumerable number of species combinations, but offers no reason, suggestion or basis for the narrow selection of the presently claimed combination of glyphosate and a pyridine analog herbicide from among the numerous combinations disclosed therein; and

(f) Hacker discloses a ratio range of glyphosate to pyridine analog herbicide clopyralid of from 60:1 to 1:20. Hacker suggests that compositions having a non-glyphosate herbicide in weight percent excess over glyphosate in a range between 1:1 to 20:1 are synergistic. Hacker therefore provides no guidance, suggestion or starting point to one skilled in the art for the selection of any co-herbicide weight ratio for any purpose or with any expectation of success.

2. In view of Hacker, it is surprising and unexpected that the narrowly selected and claimed glyphosate to pyridine analog ratio of 7.6:1 to 20:1 as required by claim 29, or 7:1 to 20:1 as required, most broadly, by claim 46 would overcome the antagonism associated with compositions having pyridine analog herbicides in weight percent excess over glyphosate.

DAW

I. I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Daniel R. Wright

Daniel R. Wright

11/1/2010
Date

MTC 6875.1
39-21(52751)B

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application of Daniel R. Wright et al. Art Unit 1616
Serial No. 10/829,572
Filed April 22, 2004
Confirmation No. 6729
For HERBICIDAL COMPOSITIONS CONTAINING GLYPHOSATE AND A PYRIDINE ANALOG
Examiner Courtney A. Brown

EXHIBIT 1 for the Declaration of Daniel R. Wright

2. Frans, R. E. 1961. Preplanting herbicides for controlling Johnsongrass in field crops. Proc. SWC 14:37–43.
3. Freeman, J. F. and T. W. Waldrep. 1963. Combination treatments of dalapon grass killer preplow and EPTC preemergence for control of Johnsongrass in corn. Down to Earth 18(3):20–23. 1963.
4. Hauser, Ellis W., J. T. Thompson, and S. V. Stacy. 1955. The effect of chemicals on the control of Johnsongrass and nutgrass with and without disking. Proc. SWC 8:399–404.
5. Pammel, J. H. and C. M. King. 1919. Johnsongrass as a weed in Southwestern Iowa. Iowa Agr. Expt. Sta. Cir. 25. 4 p.
6. Rea, H. E. 1955. The effectiveness of dalapon in controlling Johnsongrass. Proc. SWC 8:394–396.
7. Ryder, Gordon J. and C. J. Willard. 1956. You can control Johnsongrass. Ohio Agr. Ext. Serv. Bull. 342.
8. Watson, A. J. 1954. Field performance of dalapon, a new grass controlling herbicide. Proc. SWC 7:200–204.

Calculating Synergistic and Antagonistic Responses of Herbicide Combinations[1]

S. R. Colby[2]

Abstract. The responses of herbicides applied singly are used in calculating the "expected" response when they are combined. The expected response for a combination is obtained by taking the product of the percent-of-control values for herbicides applied alone and dividing by $(100)^{n-1}$ where n is the number of herbicides in the combination.

In spite of the tremendous increase in testing of herbicide combinations, the words "synergistic" and "antagonistic" have been largely avoided in publication of results. Uncertainty in determining "expected" responses for herbicide combinations may be partially responsible for the failure of workers to report synergism and antagonism. Another difficulty frequently encountered is that the herbicides used in combination are not applied singly in the same study. When herbicides have not been applied singly, there is no basis for predicting the response when they are applied in combination.

Several mathematical methods are available for testing the additivity of herbicide combinations (3, 6). This paper presents a method which facilitates calculating "expected" responses of herbicide combinations. The "expected" response for a given combination of two herbicides can be calculated as follows (3, 5):

If X = the percent inhibition of growth by herbicide A at p lb/A
and Y = the percent inhibition of growth by herbicide B at q lb/A
and E = the expected percent inhibition of growth by herbicides A + B at p + q lb/A
then, according to Gowing (3):

$$E = X + \frac{Y\,(100-X)}{100} \qquad (I)$$

Algebraic manipulation of terms in equation I yields equation II, the form used by Limpel *et al.* (5):

$$E = X + Y - \frac{XY}{100} \qquad (II)$$

When the observed response is greater than expected, the combination is synergistic; when less than expected, it is antagonistic. If the observed and expected responses are equal, the combination is additive.

In the use of equation II, original units of data, such as weed counts or fresh or dry weights of plants, are converted to "percent inhibition" values. Once this is done, it is necessary to perform one addition, a subtraction, a multiplication, and one division to obtain each expected response (equation II).

If instead, we convert the original data to "percent-of-control" values, the number of arithmetic operations required to obtain "E" is reduced.

Let X_1 = growth as a percent-of-control with herbicide A at p lb/A
and Y_1 = growth as a percent-of-control with herbicide B at q lb/A
and E_1 = expected growth as a percent-of-control with herbicides A + B at p + q lb/A
then $E_1 = 100 - E$
$X_1 = 100 - X$
$Y_1 = 100 - Y$

hence $E_1 = 100 - (X + Y - \frac{XY}{100})$

and $E_1 = 100 - ((100-X_1) + (100 - Y_1) - \frac{(100 - X_1)\,(100 - Y_1)}{100})$

finally $E_1 = \frac{X_1\,Y_1}{100}$ (III)

The use of formula III as compared with formula II eliminates the addition and subtraction, thus reducing the number of operations required to obtain an "expected" response.

Colby (2) extended formula I to apply to three-way combinations.

Thus, if Z = the percent inhibition of growth by herbicide C at r lb/A

$$\text{then } E = X + Y + Z - \frac{(XY + XZ + YZ)}{100} + \frac{XYZ}{10{,}000} \qquad (IV)$$

[1]Received for publication April 11, 1966. Contribution No. 3796 and Scientific Article No. A 1271 of the Maryland Agricultural Experiment Station, Department of Agronomy, University of Maryland, College Park.

[2]Assistant Professor, Agronomy Department, University of Maryland, College Park.

Now if Z_1 = growth as a percent-of-control with herbicide

C at r lb/A

then $E_1 = \frac{X_1 Y_1 Z_1}{10{,}000}$ (V)

Obviously, the use of formula V instead of IV reduces the number of arithmetic operations required to obtain the expected response since the subtractions and additions are eliminated. In general, the expected response for any combination of herbicides may be obtained by taking the product of the percent-of-control values for herbicides applied alone and dividing by $(100)^{n-1}$ where n is the number of herbicides in the combination. Each herbicide must be applied singly at the same rate as used in combination.

Data published by Jagschitz and Skogley (4) are used to illustrate the calculation of expected responses for herbicide combinations. Four herbicides were applied singly and in certain combinations for the control of several weeds in turfgrass. The data as originally presented have been converted to percent-of-control values and are shown in Tables 1 and 2. Expected values for the combinations are shown in

Table 1. Dandelion control in fairway turf treated with various herbicides October 8, 1961.[a]

Herbicide	lb/A		Dandelion response, %-of-control, 10–7–65[b]	
dicamba	0.125		55	
	0.25		25	
	0.5		43	
mecoprop	0.5		97	
	1.0		81	
	1.5		79	
2,4-D	0.5		63	
	1.0		54	
	1.5		44	
picloram	0.0625		40	
	0.25		10	
dicamba + mecoprop	0.125 + .5		51	(53) + 2
	0.125 + 1.0		33	(45) +12
dicamba + 2,4-D	0.125 + 0.5		51	(35) −16
	0.125 + 1.0		66	(30) −34
	0.25 + 1.0		58	(14) −44
	0.5 + 1.0		46	(23) −23
mecoprop + 2,4-D	0.5 + 0.5		56	(61) + 5
	0.5 + 1.0		47	(52) + 5
	1.0 + 0.5		43	(51) + 8
	1.0 + 1.0		57	(44) −13
	1.5 + 1.0		76	(43) −33
dicamba + mecoprop + 2,4-D	0.125 + 0.5 + 0.5		63	(34) −29
	0.125 + 1.0 + 0.5		31	(28) − 3
	0.125 + 0.5 + 1.0		52	(29) −23
	0.125 + 1.0 + 1.0		54	(24) −30
dicamba + mecoprop + 2,4-D + picloram	0.125 + 0.5 + 0.5 + 0.0625		77	(13) −64

[a]Adapted from the data of Jagschitz and Skogley (4).
[b]Expected responses for combinations are shown in parentheses following each observed response. The differences between observed and expected values also are shown by a plus sign to indicate synergism and a minus, antagonism.

parentheses following each observed value. To the right of each expected value, the difference between observed and expected values is shown. A positive value is indicative of a synergistic response while a negative value is indicative of an antagonistic response. If the observed and expected values had been computed individually for each replication, then a chi-square test could have been used to determine the statistical significance of the differences between observed and expected values. Even without the chi-square test, several conclusions seem probable from the data in Tables 1 and 2. First, the combinations appear antagonistic on dandelion. Furthermore, the antagonism seems to be greater with increasing combined rates, especially when the herbicides were applied in 1964. Possibly this antagonism is caused by greater contact injury or more plant tops being killed at higher rates resulting in less translocation of herbicide into the dandelion roots. It also appears from Table 2 that different weeds respond differently to the same

Table 2. Chickweed and dandelion control in fairway turf treated with various herbicides May 25, 1965.[a]

Herbicide	lb/A		Chickweed response, %-of-control, 10–19–65[b]		Dandelion response, %-of-control, 10–19–65[b]	
dicamba	0.125		40		66	
	0.25		1		53	
	0.5		0		49	
Mecoprop	0.5		16		87	
	1.0		0		62	
	1.5		0		72	
2,4-D	0.5		51		75	
	1.0		32		64	
	1.5		71		36	
dicamba + mecoprop	0.125 + .5		1	(6) + 5	70	(57) −13
	0.125 + 1.0		0	(0)	28	(41) +13
dicamba + 2,4-D	0.125 + .5		9	(20) +11	67	(50) −17
	0.125 + 1.0		3	(13) +10	21	(42) +21
	0.25 + 1.0		0	(3) + 3	41	(34) − 7
	0.5 + 1.0		0	(0)	53	(31) −22
mecoprop + 2,4-D	0.5 + .5		1	(8) + 7	77	(65) −12
	0.5 + 1.0		1	(5) + 4	68	(56) −12
	1.0 + 0.5		1	(0) − 1	70	(47) −23
	1.0 + 1.0		1	(0) − 1	55	(40) −15
	1.5 + 1.0		1	(0) − 1	69	(46) −23
dicamba + mecoprop + 2,4-D	0.125 + 0.5 + 0.5		1	(3) + 2	57	(43) −14
	0.125 + 1.0 + 0.5		0	(0)	64	(31) −33
	0.125 + 0.5 + 1.0		0	(2) + 2	54	(37) −17
	0.125 + 1.0 + 1.0		0	(0)	29	(26) − 3

[a]Adapted from the data of Jagschitz and Skogley (4).
[b]Expected responses for combinations are shown in parentheses following each observed response. The differences between observed and expected values also are shown by a plus sign to indicate synergism and a minus, antagonism.

combination. Thus, combinations which were about additive or possibly synergistic on chickweed were antagonistic, in general, on dandelion.

The calculations involved in determining the expected response of one three-way combination from Table 1 illustrate the efficiency of formula V compared to formula IV. For example, using dicamba at 0.125 lb/A in combination with mecoprop at 0.5 lb/A and 2,4-D at 0.5 lb/A the expected response is calculated as follows using formula IV and the data in terms of percent weed control as originally reported by Jagschitz *et al.* (4).

$$E = 45 + 3 + 37 - \frac{(45(3) + 45(37) + 3(37))}{100} + \frac{(45)\ (3)\ (37)}{10{,}000}$$

$$= 85 - \frac{(135 + 1665 + 111)}{100} + \frac{4995}{10{,}000}$$

$$= 85 - 19.11 + 0.50$$

$$= 66.39\% \text{ weed control expected}$$

Using formula V and percent-of-control values, the computation is

$$E_1 = \frac{(55)\ (97)\ (63)}{10{,}000}$$

$$= 33.61 \text{ percent-of-control}$$

and 33.61%-of-control is equal to 66.39% weed control.

Obviously, there are practical limitations in using mathematical formulas in predicting the responses for herbicide combinations. The methods described here are approximations, but they represent an improvement over no attempt to predict responses. The computations described should most effectively be applied to populations of single species although this would not seem to be an absolute requirement. Furthermore, the formulas are most accurate when values of X, Y, and Z are near the 50% level since the dose-response curves deviate least from linearity at the 50% level.

Literature Cited

1. Colby, S. R. and G. F. Warren. 1963. Herbicides: combination enhances selectivity. Science 141:3578.
2. Colby, S. R. 1965. Greenhouse evaluation of herbicide combinations. Proc. NEWCC 19:312–320.
3. Gowing, D. P. 1960. Comments on tests of herbicide mixtures. Weeds 8:379–391.
4. Jagschitz, J. A. and C. R. Skogley. 1966. Dicamba, mecoprop and 2,4-D combinations for the control of clover, chickweed and dandelion in turfgrass. Proc. NEWCC 20:496–501.
5. Limpel, L. E., P. H. Schuldt, and D. Lamont. 1962. Weed control by dimethyl tetrachloroterephthalate alone and in certain combinations. Proc. NEWCC 16:48–53.
6. Tammes, P. M. L. 1964. Isoboles, a graphic representation of synergism in pesticides. Neth. J. Plant. Path. 70:73–80.

Seasonal Variation in Sprouting and Available Carbohydrate in Yellow Nutsedge Tubers[1]

R. B. Taylorson[2]

Abstract. Two morphological types of tubers of yellow nutsedge (*Cyperus esculentus* L.) were collected over a 2-year period and were sprouted in the laboratory. Tuber dormancy occurred during late summer and early fall. Sprouting was highest during the winter and spring. Mechanical disturbance of the nutsedge stand increased tuber sprouting. Available carbohydrates followed a pattern similar to sprouting: minimum levels were found during late summer. The two types of tubers appeared to be similar in respect to the characteristics studied.

Introduction

Dormancy commonly occurs in various organs and at different seasons of the year among species of higher plants (7). Generally, little is known of dormancy in subterranean organs of weeds, including tubers of yellow nutsedge (*Cyperus esculentus* L.). Tumbleson and Kommedahl (6) indicated that tubers were dormant when dug in September but would germinate in June. Breaking of tuber dormancy was thought to be associated with low temperature and leachable inhibitors. Other research has dealt mainly with methods of breaking dormancy of tubers by chemical techniques (2). Control of yellow nutsedge with postemergence herbicides is partially dependent on tuber dormancy, since emergence of shoots must be optimum when the herbicides are applied for maximum effects.

Another factor often related to effectiveness of herbicides in the control of perennial weed species is the level of reserve carbohydrates. However, studies attempting to relate carbohydrate levels with herbicide susceptibility have not been clearly successful (4, 5).

In these studies, I have attempted to characterize tuber dormancy and carbohydrate content and their possible relation to herbicide utilization.

Methods and Materials

A dense stand of yellow nutsedge growing in a field of Tifton loamy sand was the source of plant material. Samples were collected at monthly intervals from July, 1962, to June, 1964. During July, 1962 to June, 1963, samples were randomly collected over the infested area. The stand was not disturbed mechanically except for an early spring plowing and harrowing. During the months of July to November, 1963, the area was subdivided into 25 by 50 ft plots. Three twice-replicated treatments were imposed. One treatment was a continuation of the mechanically undisturbed stand mentioned above. Other treatments were (a) mowing approximately 2 weeks prior to the next sampling date and (b) disk-harrowing approximately 2 weeks prior to the next sampling date. At the conclusion of this sampling period, further collections were made only from the mechanically undisturbed plots.

At each sampling date, duplicate lots of approximately 500 tubers were recovered by working the soil through a coarse screen. On several occasions during 1963, unwashed tubers were recovered from mechanically undisturbed plot samples by searching the soil samples and brushing off most of the adhering soil from the tubers.

Except for the unwashed lots, the tubers were subjectively graded into four types according to external color and morphology, and then counted. Type A tubers were black-skinned, shriveled, and usually dead; type B were black but turgid; type C were brown and turgid;

[1]Received for publication February 24, 1966. Cooperative investigations of the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, and the Coastal Plain Experiment Station, Tifton, Georgia.

[2]Plant Physiologist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Tifton, Georgia. Present address is Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Maryland.

MTC 6875.1
39-21(52751)B

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

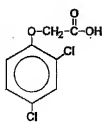
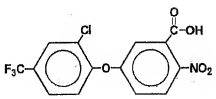
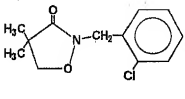
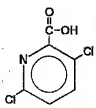
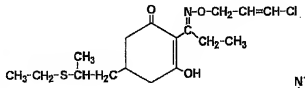
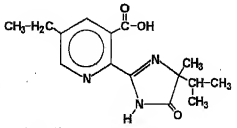
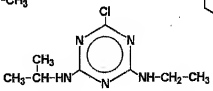
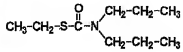
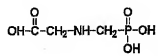
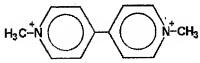
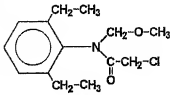
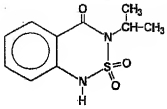
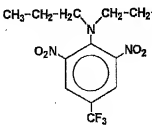
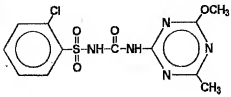
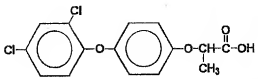
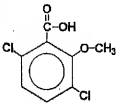
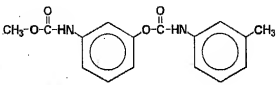
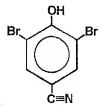
Application of Daniel R. Wright et al. Art Unit 1616
Serial No. 10/829,572
Filed April 22, 2004
Confirmation No. 6729
For HERBICIDAL COMPOSITIONS CONTAINING GLYPHOSATE AND A PYRIDINE ANALOG
Examiner Courtney A. Brown

EXHIBIT 2 for the Declaration of Daniel R. Wright

HERBICIDE HANDBOOK

Weed Science Society of America

Eighth Edition – 2002

HERBICIDE HANDBOOK

Eighth Edition

2002

Editor: William K. Vencill

Herbicide Handbook Committee[1]:

William K. Vencill (chair)
Kevin Armbrust
H. Gary Hancock
David Johnson
Greg McDonald
Diane Kintner
Frank Lichtner
Henry McLean
Jeremy Reynolds
Doug Rushing
Scott Senseman
Don Wauchope

Published by

Weed Science Society of America
810 E. 10th Street
Lawrence, KS 66044-8897
U. S. A.

ISBN 1-891276-33-6

[1]See page vii for affiliations.

GLYPHOSATE

N-(phosphonomethyl)glycine

Nomenclature

Common name: glyphosate (ANSI, BSI, ISO, WSSA).

Manufacturers, products, and formulations

Agriliance: SILHOUETTE®, 360 g ae/L (3 lb ae/gal), isopropylamine (ipa) salt, SL.

Albaugh: GLY STAR Original, 365 g ae/L, ipa salt, SL; GLY STAR 5, 480 g ae/L, ipa salt, SL; GLY STAR 5 PLUS, 480 g ae/L, ipa salt, SL; FALLOW STAR® , mix of glyphosate + dicamba at 194 + 46 g ae/L (1.6 + 0.4 lb ae/gal), ipa salts, SL.

BASF: BACKDRAFT®, mix **of imazaquin + glyphosate at 178 + 149 g/L (1.5 + 1.25 lb/gal); EXTREME®, mix of imazethapyr + glyphosate at 258 + 238 g/L (2.17 + 2 lb/gal), SL.**

CerexAgri: AQUANEAT®, 5.4 lb ai/gal, SL.

Cheminova: **GLYFOS®, 365 g ae/L, ipa salt, SL**; GLYFOS XTRA®, **365 g ae/L, ipa salt, SL**.

Dow AgroSciences: GLYPHOMAX®, **360 g ae/L, ipa salt, SL;** GLYPHOMAX PLUS®, **360 g ae/L, ipa salt, SL**; GLYPRO®, **480 g ae/L, ipa salt, SL**; GLYPRO PLUS®, **480 g ae/L, ipa salt, SL.**

Dupont: DUPONT GLYPHOSATE®, **360 g ae/L, ipa salt, SL**; DUPONT GLYPHOSATE VMF®, **480 g ae/L, ipa salt, SL**; STAPLE PLUS, a mix of pyrithiobac + glyphosate at 1.7 + 40.2%, isopropylamine salt, SL.

Griffin: GLYPHOSATE ORIGINAL, 365 g ae/L, ipa salt, SL; EAGRE, 480 g ae/L, ipa salt, SL.

Helena: RATTLER®, 360 g ae/L, ipa salt, SL.

Micro-Flo: GLY-PO, 356 g ae/L, ipa salt, SL.

Monsanto: ACCORD®, ACCORD CONCENTRATE®, ROUNDUP®, ROUNDUP® ORIGINAL, ROUNDUP® ORIGINAL RT, ROUNDUP® ULTRA, ROUNDUP® ULTRA RT, 360 g ae/L, ipa salt, SL; ACCORD® SP, RODEO®, POLADO®, ROUNDUP® CUSTOM, ROUNDUP® ULTRAMAX 480 g ae/L (4 lb ae/gal), ipa salt, SL; ROUNDUP® D-PAK, 570 g ae/L (4.75 lb ae/gal), ipa salt, SL; P, ROUNDUP® ULTRADRY, 71.4%, ipa salt, SP; ; CAMPAIGN® and LANDMASTER® BW, mix of glyphosate + 2,4-D at 108 + 192 g ae/L (0.9 + 1.6 lb ae/gal), ipa salts, SL; FALLOW MASTER® , mix of glyphosate + dicamba at 194 + 46 g ae/L (1.6 + 0.4 lb ae/gal), ipa salts, SL; FIELDMASTER®, mix of acetochlor + atrazine + glyphosate at 240 + 180 + 90 g ae/L (2 + 1.5 + 0.75 lb ae/gal), SL; RRADY MASTER ATZ®, mix of atrazine + glyphosate at 240 + 178 g ae/L (2 + 1.5 lb ae/gal), SL.

UAP-Platte: MIRAGE®, 360 g ae/L, ipa salt, SL.

Riverdale: AQUANEAT®, 5.4 lb ai/gal; RAZOR® 4EC, 4 lb ai/gal, SL.

Syngenta: TOUCHDOWN® 5- 595 g ai/L (5 lb ai/gal), trimethylsulfonium (tms) salt, SL; TOUCHDOWN® 4, 480 g ai/L (4 lb ai/gal), diammonium salt, SL; TOUCHDOWN PRO, 3 lb ai/gal, diammonium salt, SL.

Other names: GLIFOSATO ESTRELLA; JCIA0224; MON-0573; PIN-UP; SC-0224; WEEDOFF; carboxymethylaminomethylphosphonic acid; sulfosate = trimethylsulfonium carboxymethylaminomethylphosphonate (IUPAC).

Chemical family: None generally accepted.

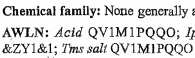
AWLN: *Acid* QV1M1PQQO; *Ipa salt* QV1M1PQQO &ZY1&1; *Tms salt* QV1M1PQQO &1-S-1&1.

CAS number: *Acid* 114370-14-8; *Ipa salt* 1071-83-6; *Tms salt* 81591-81-3.

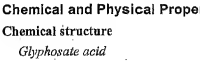
Chemical and Physical Properties

Chemical structure

Glyphosate acid

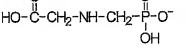


Glyphosate isopropylamine salt



Glyphosate trimethylsulfonium (trimesium) salt

Glyphosate diammonium salt



Molecular formula: *Acid* $C_3H_8NO_5P$; *Isopropylamine (Ipa) salt* $C_6H_{17}N_2O_5P$; *Trimethylsulfonium (Tms) salt* $C_6H_{15}NO_5PS$;

diammonium salt..

Molecular weight: *Acid* 169.07; *Ipa salt* 228.19; *Tms salt* 245.23.

Description: *Acid* White solid, odorless; *Tms salt* Clear amber to yellow liquid, and slight sulfur odor as the 70% aqueous technical (dry pure glyphosate tms salt is strongly hygroscopic and difficult to maintain; thus, a 70% aqueous solution is used as the "technical").

Density *Acid* 1.74 g/mL; *70% Aqueous tms salt* 1.23-1.25 g/mL at 20°C.

Melting point: 200°C (with decomposition)

Boiling point: *Acid* Unknown; *70% Aqueous tms salt* 109°C at 160 mm Hg.

Vapor pressure: *Acid* 2.45×10^{-8} kPa (1.84×10^{-7} mm Hg) at 45°C; *Tms salt* 3.99×10^{-8} kPa (3×10^{-7} mm Hg) at 25°C.

Stability: *Acid* Stable for 32 d at 25°C and pH 5, 7, or 9; *Tms salt* Stable for 32 d at 25°C and pH 7 or 9.

Solubility

Acid
water 25°C, 15,700 mg/L at pH 7, and 11,600 mg/L at pH 2.5.

Isopropylamine salt
water 25°C, 900,000 mg/L at pH 7 (estimated) (ref. 10), and 786,000 mg/L at pH 4.06.

Trimethylsulfonium salt
water 4,300,000 mg/L at 25°C and pH 7.

pK_a: *Acid* 2.6, 5.6, and 10.3.

K_{ow}: 0.0006-0.0017

Herbicidal Use

Glyphosate is nonselective, foliar-applied, and can be used as follows: preplant or PRE at 0.21-2.24 kg ae/ha (0.188-2 lb ae/A) to control emerged weeds at planting in certain annual crops planted using no-till methods; POST at 0.84-4.2 kg ae/ha (0.75-3.75 lb ae/A) or at 0.5-5% v/v of a 360 g/L product in a spray-to-wet application for general vegetation control in many noncrop areas such as industrial sites; directed POST or for site preparation at up to 4.2 kg ae/ha in ornamentals and Christmas trees; directed POST at 0.84-4.2 kg ae/ha in tree and vine crops; preharvest at 0.84-4.2 kg ae/ha in cotton; preharvest at 0.21-0.84 kg ae/ha in wheat; POST at 0.16 kg ae/ha (0.14 lb ae/A) in bahiagrass and Kentucky bluegrass, POST at 0.16-0.42 kg ae/ha (0.14-0.375 lb ae/A) in bermudagrass, and POST at 0.21 kg ae/ha in fescues, orchardgrass, and quackgrass for suppression of these perennial grasses on orchard floors; and for control of woody vegetation by injection or frill treatment or by treating cut stumps. Glyphosate can be applied with a conventional sprayer, or with recirculating sprayers, shielded applicators, and wiper applicators. It controls virtually all annual and perennial weeds, but generally is most phytotoxic to annual grasses. A non-ionic surfactant is required for maximum efficacy, although certain formulated products already contain surfactant. In addition, selected formulations can be used POST in genetically modified crops tolerant to glyphosate (see mechanism of resistance section) such as soybean, corn, cotton, canola.

Use Precautions

Fire hazard: All aqueous products (ROUNDUP, RODEO, etc.) are nonflammable; flash point is >93°C (>200°F) (TCC).

Corrosiveness: Corrosive to iron and galvanized steel; do not hold spray mixtures in galvanized or unlined steel tanks (except stainless) for extended periods.

Storage stability: All products containing only glyphosate isopropylamine salt are stable at <60°C (140°F); they freeze at -29°C (-20°F) but can be used upon thawing. Package mixtures may have different characteristics. **Cleaning glassware/spray equipment:** Clean glassware with water. Flush sprayer parts with several changes of water.

Emergency exposure: Glyphosate is a potential irritant. No specific antidote is available. Flush eyes with water for at least 15 min. If ingested, immediately dilute by swallowing milk or water.

Incompatibilities: Tank mixing with residual herbicides such as substituted ureas and triazines or with POST herbicides such as paraquat, dalapon, MSMA, phenoxy, or other auxin-type herbicides may reduce glyphosate efficacy.

Behavior in Plants

Symptomology: Growth is inhibited soon after application followed by general foliar chlorosis and necrosis within 4-7 d for highly susceptible grasses and within 10-20 d for less susceptible species. Chlorosis may appear first and be most pronounced in immature leaves and growing points. Foliage sometimes turns reddish-purple in certain species. Regrowth of treated perennial and woody species often appears deformed with whitish markings or striations; multiple shoots (sometimes called a witch's broom) may develop at the nodes.

Absorption: Moderately absorbed across the cuticle when POST applied (3, 13). The isopropylamine salt of glyphosate is more readily absorbed than is glyphosate acid, and surfactant and ammonium sulfate further increase absorption of the isopropylamine salt (12). Glyphosate transport across the plasmalemma is slower than most herbicides (especially nonpolar herbicides) (9), probably because of its negative charge at physiological pH. A phosphate transporter may contribute to glyphosate movement across the plasmalemma (5).

Translocation: Primarily translocated in the symplast with accumulation in underground tissues, immature leaves, and meristems (14). Apoplastic translocation has been observed in tall morningglory (6) and quackgrass (10), but most results suggest little to no apoplastic movement. Glyphosate may interfere with its own translocation from treated leaves by interfering with carbon partitioning and metabolism (8).

Mechanism of action: Inhibits 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase (1) which produces EPSP from shikimate-3-phosphate and phosphoenolpyruvate in the

For symbol and abbreviation definitions, see page 453.

shikimic acid pathway. EPSP inhibition leads to depletion of the aromatic amino acids tryptophan, tyrosine, and phenylalanine, all needed for protein synthesis or for biosynthetic pathways leading to growth. The failure of exogenous addition of these amino acids to completely overcome glyphosate toxicity in higher plants (7, 11) suggests that factors other than protein synthesis inhibition may be involved. Although plant death apparently results from events occurring in response to EPSP synthase inhibition, the actual sequence of phytotoxic processes is unclear.

HRAC/WSSA Group Designation: HRAC - G/ WSSA - 9.

Metabolism in plants: Not appreciably metabolized when applied at phytotoxic rates. Glyphosate is slowly metabolized to amino methylphosphonic acid (4, 15).

Non-herbicidal biological properties: Sublethal rates inhibit seedhead emergence and suppress vegetative growth of most perennial grasses.

Mechanism of resistance in weeds: *Lolium rigidum* in S. Africa and Australia; *Conyza canadensis* in Delaware.

Engineered tolerance in crops: Available in several species, including tobacco, tomato, petunia, corn, chicory, cotton, canola, carrot, *Corydalis*, and certain bacteria species. Glyphosate-resistant soybean cultivars may be commercially released in 1995 or 1996.

Behavior in Soil

Sorption: Rapidly and tightly adsorbed to soil. OM, clay, silt, or sand content and soil pH have minimal effect on adsorption. Glyphosate adsorption correlates with the amount of vacant phosphate sorption sites and may occur through binding of the phosphonic acid moiety. High levels of metallic cations in clay soils increase the amount of glyphosate adsorbed. Strong adsorption to soils is evidenced in part by low phytotoxicity with soil applications. Crops can be seeded or transplanted immediately into treated areas.

K_{oc}: Average is 24,000 mL/g (estimated) (16).

K_d: 324-600 for a silty clay loam and a loamy sand.

Transformation

Photodegradation: Negligible losses.

Other degradation: Degraded microbially in soil and water. Decomposition rates vary with soil and microbial population. From 10 to 70% of glyphosate may be transformed to CO_2 over a growing season or less. Non-microbial degradation rates are negligible.

Persistence: Glyphosate has moderate persistence with a typical field half-life of 47 d (16). All crops can be planted immediately after application due to strong adsorption to soil.

Lab experiments: Half-life typically is <25 d.

Mobility: Low mobility on most soils in field and lab studies because of strong adsorption to soil. Low potential for movement in runoff in field and lab studies.

Volatilization: Negligible losses.

Toxicological Properties

Toxicity tests were conducted with technical grade glyphosate acid unless otherwise indicated.

Acute toxicity

Glyphosate acid technical: Oral LD_{50} rat 5600 mg/kg; Dermal LD_{50} rabbit >5000 mg/kg; 4-h Inhal. LC_{50} NAv; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, slight.

Glyphosate isopropylamine salt technical: Oral LD_{50} rat >5000 mg/kg; Dermal LD_{50} rabbit >5000 mg/kg; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, slight.

Glyphosate trimethylsulfonium salt technical: Oral LD_{50} male rat 748 mg/kg, female rGlyphosateat 755 mg/kg; Dermal LD_{50} rabbit >2000 mg/kg; 4-h Inhal. LC_{50} >5.18 mg/L; Skin irrit. rabbit, mild; Skin sensitiz. guinea pig, mild; Eye irrit. rabbit, mild.

ROUNDUP: Oral LD_{50} rat >5000 mg/kg; Dermal LD_{50} rabbit >5000 mg/kg; 4-h Inhal. LC_{50} rat 3.2 mg/L; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, moderate.

RODEO: Oral LD_{50} rat >5000 mg/kg; Dermal LD_{50} rabbit >5000 mg/kg; 4-h Inhal. LC_{50} rat >1.3 mg/L; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, none.

LANDMASTER BW: Oral LD_{50} rat 3860 mg/kg; Dermal LD_{50} rabbit 6366 mg/kg; Skin irrit. rabbit, moderate; Eye irrit. rabbit, severe.

Subchronic toxicity

90-d dietary, mouse: NOEL 2300 mg/kg/d (10,000 ppm); decreased weight gains at 50,000 ppm.

90-d dietary, rat: NOEL >1400 mg/kg/d (>20,000 ppm).

21-d dermal, rabbit: Systemic NOEL >5000 mg/kg/d; slight irritation at site of application at 5000 mg/kg/d.

Chronic toxicity

24-mo dietary, mouse: Oncogenic NOEL 4500 mg/kg/d (30,000 ppm); slightly lower body weight gains and several microscopic liver changes at 4500 mg/kg/d; not carcinogenic.

24-mo dietary, rat: NOEL 400 mg/kg/d (8000 ppm); not carcinogenic; reduced body weight gains in females and eye changes at 1000 mg/kg/d (20,000 ppm).

12-mo dietary, dog: NOEL 500 mg/kg/d; no effects.

Teratogenicity

Rat: NOEL 1000 mg/kg/d; maternal and fetal mortality at 3500 mg/kg/d; not teratogenic.

Rabbit: NOEL maternal 175 mg/kg/d, fetal >350 mg/kg/d; maternal toxicity at 350 mg/kg/d; no fetal toxicity.

Reproduction

Rat: NOEL ~700 mg/kg/d (10,000 ppm); not a reproductive toxin; decreased adult and pup body weight gains and possible changes in litter size at ~2100 mg/kg/d (30,000 ppm).

Mutagenicity

Gene mutation: Ames test, negative; *E. coli*, negative; *B.*

For symbol and abbreviation definitions, see page 453.

subtilis rec+ and rec-, negative; CHO/point mutation, negative.

Structural chromosome aberration: Mouse dominant lethal, negative; Rat bone marrow/cell clastogenesis, negative.

DNA damage/repair: Rat primary culture/DNA repair, negative.

Wildlife

Glyphosate acid technical: Bobwhite quail, oral LD_{50} >4640 mg/kg, 8-d dietary LC_{50} >4640 ppm; Mallard duck 8-d dietary LC_{50} 4640 ppm; Honey bee, oral LD_{50} >100 µg/bee, topical LD_{50} >100 µg/bee; Daphnia 48-h LC_{50} 780 mg/L; Bluegill sunfish 96-h LC_{50} 120 mg/L; Harlequin fish 96-h LC_{50} 168 mg/L; Rainbow trout 96-h LC_{50} 86 mg/L; Atlantic oyster 96-h LC_{50} >10 mg/L; Fiddler crab 96-h LC_{50} 934 mg/L; Shrimp 96-h LC_{50} 281 mg/L.

Glyphosate trimethylsulfonium salt technical: Bobwhite quail 8-d dietary LC_{50} >5000 ppm; Mallard duck, oral LD_{50} 950 mg/kg, 8-d dietary LC_{50} >5000 ppm; Honey bee topical LD_{50} >62.1 µg/bee; Daphnia 48-h LC_{50} 71 mg/L; Bluegill sunfish 96-h LC_{50} 3500 mg/L; Rainbow trout 96-h LC_{50} 1800 mg/L; Mysid shrimp 96-h LC_{50} 17.4 mg/L.

ROUNDUP: Earthworm LC_{50} in soil >5000 ppm; Honey bee, oral LD_{50} >100 µg/bee, topical LD_{50} >100 µg/bee; Daphnia 48-h LC_{50} 5.3-37 mg/L; Bluegill sunfish 96-h LC_{50} 5.8-14 mg/L; Carp 96-h LC_{50} 19.7 mg/L; Catfish 96-h LC_{50} 16 mg/L; Fathead minnow 96-h LC_{50} 9.4 mg/L; Rainbow trout 96-h LC_{50} 8.2-26 mg/L; Crayfish 96-h LC_{50} >1000 mg/L.

RODEO: Daphnia 48-h LC_{50} 930 mg/L; Bluegill sunfish 96-h LC_{50} >1000 mg/L; Carp 96-h LC_{50} >10,000 mg/L; Rainbow trout 96-h LC_{50} >1000 mg/L.

Use classification: General Use for most products.

Synthesis and Analytical Methods

Synthesis: Not available.

Purification of technical: Recrystallize three times from water.

Analytical methods: Assay method for formulated product uses HPLC. Separation is obtained using a strong anion exchange column and a phosphate buffered mobile phase. AOAC Official Method is 983.10.

Historical: Herbicidal activity was first reported in 1971 (2). Glyphosate-isopropylammonium salt and glyphosate-sesquisodium salt were introduced by Monsanto Company. The trimethylsulfonium salt was introduced in Spain in 1989 by ICI Agrochemicals. U.S. patent 3,799,758 was awarded to Monsanto. European patent 53,871 and U.S. patent 4,315,765 both were awarded to ICI.

Information Sources

Primary industry sources: Monsanto and Syngenta.

References

1. Amrhein, N. et al. 1980. Plant Physiol. 66:830.
2. Baird, D. D. et al. 1971. Proc. North Cent. Weed Control Conf. 26:64.
3. Boerboom and Wyse. 1988. Weed Sci. 36:291.
4. Coupland, D. 1984. Pestic. Sci. 15:226.
5. Denis and Delrot. 1993. Physiol. Plant. 87:569.
6. Dewey and Appleby. 1983. Weed Sci. 31:308.
7. Duke and Hoagland. 1978. Plant Sci. Lett. 11:185.
8. Geiger and Bestman. 1990. Weed Sci. 38:324.
9. Jachetta, J. J. et al. 1986. Plant Physiol. 82:1000.
10. Klevorn and Wyse. 1984. Weed Sci. 32:744.
11. Lee, T. T. 1980. Weed Res. 20:365.
12. MacIsaac, S. A. et al. 1991. Pestic. Sci. 31:53.
13. Marshall, G. et al. 1987. Pestic. Sci. 18:55.
14. Martin and Edgington. 1981. Pestic. Biochem. Physiol. 16:87.
15. Sandberg, C. L. et al. 1980. Weed Res. 20:195.
16. Wauchope, R. D. et al. 1992. Rev. Environ. Contam. Toxicol. 123:1.

For symbol and abbreviation definitions, see page 453.

MTC 6875.1
39-21(52751)B

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

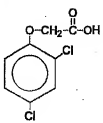
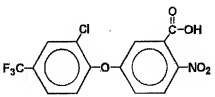
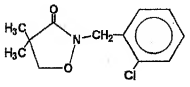
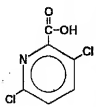
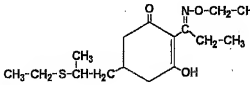
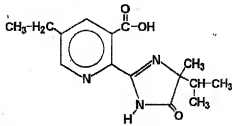
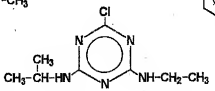
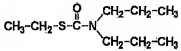
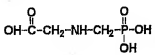
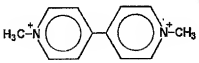
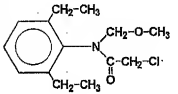
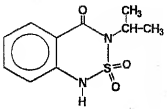
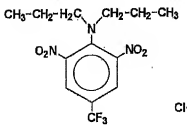
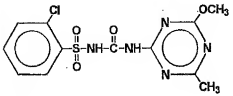
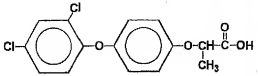
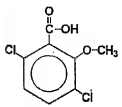
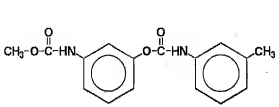
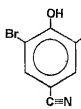
Application of Daniel R. Wright et al. Art Unit 1616
Serial No. 10/829,572
Filed April 22, 2004
Confirmation No. 6729
For HERBICIDAL COMPOSITIONS CONTAINING GLYPHOSATE AND A PYRIDINE ANALOG
Examiner Courtney A. Brown

EXHIBIT 3 for the Declaration of Daniel R. Wright

HERBICIDE HANDBOOK

Weed Science Society of America

Eighth Edition – 2002

HERBICIDE HANDBOOK

Eighth Edition

2002

Editor: William K. Vencill

Herbicide Handbook Committee[1]:

William K. Vencill (chair)
Kevin Armbrust
H. Gary Hancock
David Johnson
Greg McDonald
Diane Kintner
Frank Lichtner
Henry McLean
Jeremy Reynolds
Doug Rushing
Scott Senseman
Don Wauchope

Published by

Weed Science Society of America
810 E. 10th Street
Lawrence, KS 66044-8897
U.S.A.

ISBN 1-891276-33-6

[1]See page vii for affiliations.

Use classification: All products are General Use.

Synthesis and Analytical Methods

Synthesis: React *N*-(2-chlorophenylmethyl)hydroxylamine with chloropivaloyl chloride, followed by ring closure with methanolic KOH.

Purification of technical: Recrystallization from organic solvents, or distillation.

Analytical methods: Reverse phase HPLC under temperature control is used for analysis of technical and formulated products. GC may be used for analysis of formulated products and is used with N-P detection or GC-MS detection for analysis of residues.

Historical: Clomazone was developed in the early 1980s and commercialized as COMMAND in 1985. It is protected under U.S. patent 4,405,357. Numerous foreign patents also have been assigned.

Information Sources

Primary information source: FMC.

References

1. Croteau, R. 1992. Plant Physiol. 98:1515.
2. Devine, M., S. O. Duke, and C. Fedtke. 1993. Physiology of Herbicide Action. Prentice Hall, New Jersey.
3. Duke, S. O. et al. 1991. Weed Sci. 39:339.
4. Liebl and Norman. 1991. Weed Sci. 39:329.
5. Scott and Weston. 1992. Weed Sci. 40:7.
6. Wauchope, R. D. et al. 1992. Rev. Environ. Contam. Toxicol. 123:1.
7. Weimer, M. R. et al. 1992. Pestic. Biochem. Physiol. 42:43.
8. Weimer, M. R. et al. 1992. Plant Physiol. 98:427.
9. Ferhatoglu, Y., M. Barett, and J. Chappell. 2002. Abstracts WSSA 42:73.

CLOPYRALID

3,6-dichloro-2-pyridinecarboxylic acid

Nomenclature

Common name: clopyralid (ANSI, BSI, WSSA).

Manufacturers, products, and formulations

Dow AgroSciences: RECLAIM™, STINGER™, LONTREL® Turf and Ornamental and TRANSLINE™, 360 g ae/L (3 lb ae/gal), monoethanolamine (mea) salt, SL; CONFRONT™, mix of triclopyr + clopyralid at 270 + 90 g ae/L (2.25 + 0.75 lb ae/gal), triethylamine salts, SL; CURTAIL™, mix of clopyralid + 2,4-D at 45.6 + 240 g ae/L (0.38 + 2 lb ae/gal), monoethanolamine and triisopropylamine salts, SL; HORNET WDG, mix of flumetsulam (18.5% ai) + clopyralid potassium salt (60.0% ai).; REDEEM Rand P, mix of triclopyr + clopyralid 270 + 90 g ae/L, triethylamine salt, SL; CURTAIL M, mix of clopyralid + MCPA 50 + 282 g ae/L, 2-ethylexyl ester, EC.

Dupont: ACCENT-GOLD®, a mix of clopyralid +

For symbol and abbreviation definitions, see page 453.

flumetsulam + nicosulfuron + rimsulfuron at 51.7 + 19.1 + 6.5 + 6.5%, DG.

Other names: CAMPAIGN; CRUSADER; 3,6-DCP; DOWCO 290; ESCORT; HARRIER; LONTREL; MAYCLENE; VULCAN; Acid dichloro-3,6 picolinique (France); 3,6-dichloropicolinic acid (Canada and Finland); 3,6-dichloropyridine-2-carboxylic acid.

Chemical family: Pyridinecarboxylic acid or picolinic acid.

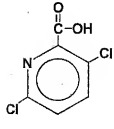
AWLN: *Acid* (6N) bVQ cG fG; *Mea salt* (6N) bVQ cG fG &Z2Q; *Tea salt* (6N) bVQ cG dZ eG fG &2J2&2.

CAS number: *Acid* 1702-17-6; *Mea salt* 57754-85-5.

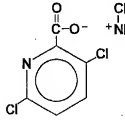
Chemical and Physical Properties

Chemical structure

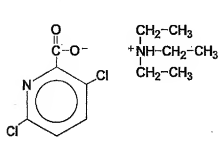
Clopyralid acid



Clopyralid monoethanolamine salt



Clopyralid triethylamine salt



Molecular formula: *Acid* $C_6H_3Cl_2NO_2$; *Monoethanolamine (Mea) salt* $C_8H_{10}Cl_2N_2O_3$; *Triethylamine (Tea) salt* $C_{12}H_{18}Cl_2N_2O_2$.

Molecular weight: *Acid* 192.00; *Mea salt* 253.09; *Tea salt* 293.19.

Description: Off-white crystalline solid, odorless.

Density: 0.298 g/mL (18.5 lb cu. Ft)

Melting point: 151-152°C

Boiling point: Not applicable.

Vapor pressure: 1.36 mPa at 25°C

Stability: Unstable in acid, oxidizing material, and halogenated organics; Stable to UV light; Decomposes above 151°C.

Solubility

Acid

water 1000 mg/L at 25°C

organic solvents g/100 mL at 25°C:

octanol 13.9

hexane 0.50

xylene 0.65

Monoethanolamine salt

water 300,000 mg/L at 25°C (ref. 7)

pK_a: 2.3

K_{ow}: -1.81 at pH 5, -2.63 at pH 7, and -2.55 at pH 9.

Herbicidal Use

Clopyralid can be applied POST at 0.105-0.28 kg ae/ha (0.094-0.25 lb ae/A) in sugarbeets, Christmas trees (conifers), grasses for seed, fallow, and field corn, and POST at 0.14-0.56 kg ae/ha (0.125-0.5 lb ae/A) in pasture, rangeland, and on Conservation Reserve land. It controls many annual and perennial broadleaf weeds including Canada thistle, wild buckwheat, cocklebur, jimsonweed, ragweed spp., marshelder, and wild sunflower.

Use Precautions

Fire hazard: STINGER, TRANSLINE, and RECLAIM are combustible; flash point is 47°C (117°F). CONFRONT is combustible; flash point is 66°C (150°F). CURTAIL is noncombustible; flash point is >91°C (>195°F).

Corrosiveness: STINGER, TRANSLINE, RECLAIM, and CONFRONT corrode brass, copper, zinc, and aluminum. CURTAIL corrodes brass and copper.

Storage stability: Stable for 2 yr. Store CONFRONT, RECLAIM, STINGER, and TRANSLINE above -2.2°C (28°F) or warm to 4.4°C (40°F) and agitate before use. Store CURTAIL above -12°C (10°F) or warm and agitate before use.

Cleaning glassware/spray equipment: Rinse and flush equipment at least three times with water; add household ammonia at 1% v/v during the second rinse.

Emergency exposure: Wash skin with soap and water. Wash eyes with water or injury may result. If CONFRONT is ingested, drink a large quantity of milk, egg whites, or gelatin solution, or, if these are not available, water. For other formulated products, induce vomiting if large amounts are ingested.

For symbol and abbreviation definitions, see page 453.

Incompatibilities: All formulated products are compatible with most types of hard water.

Behavior in Plants

Symptomology: Symptoms are typical of other auxin-type herbicides, and include epinastic bending and twisting of stems and petioles, stem swelling (particularly at nodes) and elongation, and leaf cupping and curling. This is followed by chlorosis at the growing points, growth inhibition, wilting, and necrosis. At low concentrations, the tips of young leaves may develop narrow feather-like extensions of the midrib.

Absorption: Readily absorbed by roots and foliage. In sunflower and rapeseed, 97% of foliar-applied clopyralid was absorbed within 24 h of application (2). Clopyralid parent acid is more rapidly absorbed than either the ester or salt forms. Under conditions of low humidity or water stress, absorption of the monoethanolamine and K salts are greatly reduced, whereas the acid and ester forms are unaffected. Uptake of clopyralid across plant membranes occurs by diffusion of the parent acid, and presumably leads to accumulation of clopyralid in cells due to ion trapping that is common with most weak acid herbicides.

Translocation: Readily transported in plant tissues, primarily via the symplasm (including the phloem). Over 50% of applied clopyralid translocated out of the treated leaves of Canada thistle within 24 h of application (3). Clopyralid accumulates at the growing points. Salt forms of clopyralid translocate less than the parent acid, but twice as much as the esters (1). This appears to result from increased partitioning of clopyralid esters in the cuticle.

Mechanism of action: Not completely understood but similar to that of endogenous auxin (IAA) and other auxin-type herbicides. The specific cellular or molecular binding site relevant to the action of IAA and the auxin-type herbicides has not been identified. Nevertheless, the primary action of these compounds appears to involve cell wall plasticity and nucleic acid metabolism. Clopyralid is thought to acidify the cell wall by stimulating the activity of a membrane-bound ATPase proton pump. The reduction in apoplasmic pH induces cell elongation by increasing the activity of enzymes responsible for cell wall loosening. Low concentrations of clopyralid also stimulate RNA polymerase, resulting in subsequent increases in RNA, DNA, and protein biosynthesis. Abnormal increases in these processes presumably lead to uncontrolled cell division and growth, which results in vascular tissue destruction. In contrast, high concentrations of clopyralid and other auxin-type herbicides inhibit cell division and growth, usually in meristematic regions that accumulate photosynthate assimilates and herbicide from the phloem. Clopyralid and other auxin-type herbicides stimulate ethylene evolution which may in some cases produce the characteristic epinastic symptoms associated with exposure to these herbicides (5).

HRAC/ WSSA Group Designation: HRAC - O/ WSSA - 4.

Metabolism in plants: Slowly metabolized in most plants. In Canada thistle, no clopyralid metabolites were found 9 d after treatment in one study, whereas 22% of the herbicide was present as water-soluble metabolites 6 d after application in another study (2, 6). Rapeseed rapidly metabolized clopyralid, with 38 and 70% converted to water-soluble metabolites 1 and 6 d after treatment, respectively (6).

Non-herbicidal biological properties: None known.

Mechanism of resistance in weeds; No known cases of resistance.

Behavior in Soil

Sorption: Weakly adsorbed. Clopyralid is dissociated and negatively charged in soil because of its low pK_a.

K_{oc}: Average is 6 mL/g (7), but ranges to 60 mL/g (increased soil sorption with time).

K_d: 0.41

Transformation

Photodegradation: Negligible losses.

Other degradation: Degraded by microbes. Non-microbial degradation does not occur.

Persistence: Moderate residual with an average field half-life of 40 d (7). Half-life was 12-70 d across a range of U.S. soils. Residues may injure certain crops (such as peas, lentils, and potatoes) planted 1 yr after application.

Mobility: Moderate leaching potential.

Volatilization: Insignificant losses.

Toxicological Properties

Toxicity tests were conducted with technical grade clopyralid acid unless otherwise indicated.

Acute toxicity

Clopyralid acid technical: Oral LD_{50} rat, mouse >5000 mg/kg; Dermal LD_{50} rabbit >2000 mg/kg; 4-h Inhal. LC_{50} rat >1.3 mg/L; Skin irrit. rabbit, none or very slight; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, severe (possible corneal injury and permanent vision impairment).

STINGER: Oral LD_{50} rat >5000 mg/kg.

Subchronic toxicity

90-d dietary, mouse: NOEL 750 mg/kg/d.

90-d dietary, rat: NOEL 300 mg/kg/d.

90-d dietary, dog: NOEL 150 mg/kg/d.

Chronic toxicity

18-mo dietary, mouse: NOEL 500 mg/kg/d; not oncogenic.

24-mo dietary, rat: NOEL 50 mg/kg/d; not oncogenic.

12-mo dietary, dog: NOEL 100 mg/kg/d.

Teratogenicity

Rat: NOEL >250 mg/kg/d; not teratogenic.

Rabbit: NOEL 110 mg/kg/d; not teratogenic.

Reproduction

Rat: NOEL 500 mg/kg/d; not a reproductive toxin.

Mutagenicity

Gene mutation: Ames test, negative; CHO/HGPRT, negative.

For symbol and abbreviation definitions, see page 453.

Structural chromosome aberration: Mouse bone marrow, negative.

DNA damage/repair: Rat UDS, negative.

Wildlife

Clopyralid acid technical: Bobwhite quail 8-d dietary LC_{50} >4640 ppm; Mallard duck, oral LD_{50} 1465 mg/kg, 8-d dietary LC_{50} >4640 ppm; Earthworm LC_{50} in soil 1000 ppm; Honey bee, oral LD_{50} 100 µg/bee, topical LD_{50} >0.1 µg/bee; Daphnia 48-h LC_{50} 232 mg/L; Bluegill sunfish 96-h LC_{50} 125 mg/L; Rainbow trout 96-h LC_{50} 104 mg/L.

Use classification: General Use for all products.

Synthesis and Analytical Methods

Synthesis: Not available.

Purification of technical: Not available.

Analytical methods: See ref. 4.

Historical: Clopyralid was discovered in 1961. The original patent has expired. Clopyralid was first marketed in 1978 in Europe. In the U.S., CURTAIL was introduced in 1987, STINGER in 1988, and CONFRONT in 1989.

Information Sources

Primary industry source: Dow AgroSciences LLC, 9330 Zionsville Road, Indianopolis, IN 46268-1054.

References

1. Bovey, R. W. et al. 1989. Weed Sci. 37:19.
2. Hall and Vanden Born. 1988. Weed Sci. 36:9.
3. O'Sullivan and Kossatz. 1984. Weed Res. 24:17.
4. Pik and Hodgson. 1976. J. AOAC 59:2.
5. Thomson and Cobb. 1987. Proc. Br. Crop Prot. Conf.-Weeds 3:1097.
6. Turnbull and Stephenson. 1985. Weed Sci. 33:143.
7. Wauchope, R. D. et al. 1992. Rev. Environ. Contam. Toxicol. 123:1.

2-generation Wistar: NOAEL 100 mg/kg/d

Mutagenicity

Four acceptable mutagenicity studies were available for review: a microbial (Salmonella typhimurium) mutagenicity assay; an in vitro mammalian (mouse lymphoma) cell gene mutation assay; an in vivo mouse bone marrow micronucleus assay; and an unscheduled DNA synthesis assay. Diflufenzopyr was negative for mutagenic potential in all assays.

Wildlife

Bobwhite quail, oral LD_{50} >2250 mg/kg; Mallard duck, oral LD_{50} >2250 mg/kg; Daphnia 48-h EC_{50} non-toxic; Bluegill sunfish 96-h LC_{50} non-toxic; Rainbow trout 96-h LC

Aquatic - Freshwater

Diflufenzopyr is slightly toxic to practically non-toxic to freshwater organisms (LC_{50} = 15 to > 135 ppm ae).

Aquatic - Estuarine/Marine

Diflufenzopyr is slightly toxic to practically non-toxic to estuarine/marine organisms (LC_{50} or EC_{50} = 18.9 to > 138 ppm ae).

Plants

Diflufenzopyr is highly toxic to terrestrial plants. Seedling emergence studies identified the turnip as the most sensitive dicot species (EC_{25} = 0.0008 pounds acid equivalent/acre) and ryegrass as the most sensitive monocot (Shoot Length EC_{25} = 0.0055 lbs. ae/A).

Use classification: General Use.

Synthesis and Analytical Methods

Synthesis: Not available.

Purification of technical: Not available.

Analytical methods: Not available.

Historical: Not available.

Information Sources

Primary industry source: BASF

DIMEFURON

N'-[3-chloro-4-[5-(1,1-dimethylethyl)-2-oxo-1,3,4-oxadiazol-3(2H)-yl]phenyl]-N,N-dimethylurea

Nomenclature

Common name: Dimefuron (ISO)

Manufacturers, products, and formulations

***Feinchemie*:** PRADONE®TS , a mix of 50% dimefuron + 25% ethofumesate (EU).

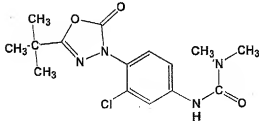
Other names: 23 465 RP

Chemical family: substituted urea

CAS number: 34205-21-5

Chemical and Physical Properties

Chemical structure:



Molecular formula: $C_{15}H_{19}ClN_4O_3$

Molecular weight: 338.8

Description: colorless, odorless crystals

Density: Not available.

Melting point: 193 C

Boiling point: Not available.

Vapor pressure: 1 x 10^{-4}Pa (20 C)

Stability: Stable in aqueous solution.

Solubility: In water, 16 mg/l (20 C). Readily soluble in chloroform; moderately soluble in acetonitrile, acetophenone, ethanol; slightly soluble in benzene, toluene, xylene.

pK_a: Non-ionized.

K_{ow}: LogP 2.51

Herbicidal Use

Applied PRE- and POST- at 0.2 to 2 kg ai/ha in field beans, certain cereals, cotton, peanut, dormant alfalfa, oilseed rape and peas.

For symbol and abbreviation definitions, see page 453.

Use Precautions

Fire hazard: Not available.
Corrosiveness: Not available.
Storage stability: Not available.
Cleaning glassware/spray equipment: Not available.
Emergency exposure: Not available.
Incompatibilities: Not available.

Behavior in Plants

Symptomology: Chlorosis of affected foliage followed by necrosis and plant death.
Absorption/translocation: Absorbed by roots and leaves. Xylem translocated.
Mechanism of action: Photosystem II inhibitor. See atrazine for more details.
HRAC/WSSA Group Designation: HRAC -C2/ WSSA- 7.
Metabolism in plants: Demethylated dimefuron is the main metabolite.
Mechanism of resistance in weeds: Not avaialble.

Behavior in Soil

Sorption: Koc = 117-262.
Other degradation: In aerobic soils, demethylated and hydroxylated *tert*-butyl metabolites of dimefuron are produced.

Toxicological Properties

Toxicity tests were conducted with technical grade dimefuron unless otherwise indicated.
Acute toxicity
Oral LD_{50} rat > 2000mg/kg; Dermal LD_{50} rabbit 1000 mg/kg; non-sensitizer for skin or eye irritant.
Subchronic toxicity
90-d dietary, rat: NOEL 150 mg/kg/d
90-d dietary, dog NOEL 20 mg/kg/d
Wildlife: Not available.
Use classification: WHO class V.

Information Sources

Primary industry source: Multiple

SONALAN HFP was introduced in 1994.

Information Sources

Primary industry source: Dow AgroSciences LLC, 9330 Zionsville Road, Indianapolis, IN 46268-1054..

References

1. Kittle, D. R. et al. 1984. Proc. North Cent. Weed Control Conf. 39:10.
2. Mudge, L. C. et al. 1984. Weed Sci. 32:591.
3. Penner, D. 1971. Weed Sci. 19:571.
4. Savage, K. 1978. Weed Sci. 26:465.
5. Skylakakis, G. et al. 1974. Proc. 12th Br. Weed Control Conf. 12:795.
6. USA EPA Registration Eligibility Decision (RED). Ethalfluralin, March 1995. EPA 738-R-95-001.
7. Vandeventer, J. W. et al. 1986. Pestic. Sci. 17:380.
8. Vaughn, K. C. et al. 1987. Plant Physiol. 83:956.
9. Vaughn, K. C. et al. 1990. Weed Technol. 4:157.
10. Vaughn and Lehnen. 1991. Weed Sci. 39:450.
11. Wauchope, R. D. et al. 1992. Rev. Environ. Contam. Toxicol. 123:1.
12. Willis and Putnam. 1985. Weed Sci. 34:13.

ETHAMETSULFURON

methyl 2-[[[[4-ethoxy-6-(methylamino)-1,3,5-triazin-2-yl]amino]carbonyl]amino]sulfonyl]benzoate

Nomenclature

Common name: ethametsulfuron (ANSI, BSI, ISO, WSSA).

Manufacturers, products, and formulations
Du Pont: MUSTER®, 75% ai, WG.

Other names: DPX-A7881; methyl 2-[(4-ethoxy-6-methylamino-1,3,5-triazin-2-yl)carbamoylsulfamoyl]benzoate (IUPAC).

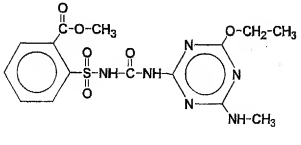
Chemical family: Sulfonylurea.

AWLN: (6N eN eN) bO2 dMVMSWR bVO1& fM1

CAS number: 97780-06-8

Chemical and Physical Properties

Chemical structure



Molecular formula: $C_{15}H_{18}N_6O_6S$

Molecular weight: 410.40

Description: White crystalline solid.

Density: Not available.

Melting point: 194°C

Boiling point: Not applicable.

Vapor pressure: 7.7 x 10^{-13} Pa at 25 C.

Stability: Not available.

Solubility

water 1.7 mg/L at pH 5, 50 mg/L at pH 7, and 410 mg/L at pH 9.

organic solvents g/100 mL:

acetone 0.16	methanol 0.035
acetonitrile 0.083	methylene chloride 0.39
ethanol 0.017	toluene 0.0009
ethyl acetate 0.068	xylenes 0.001
n-hexane <0.0005	

pK_a: 4.6

K_{ow}: 0.89 at pH 7

Herbicidal Use

Ethametsulfuron can be applied POST at 20-30 g ai/ha (0.286-0.43 oz ai/A) in spring canola (rapeseed) for control of certain broadleaf weeds such as wild mustard, hempnettle, green

For symbol and abbreviation definitions, see page 453.

smartweed, and stinkweed.

Use Precautions

Fire hazard: Not available.

Corrosiveness: Not available.

Storage stability: Not available.

Cleaning glassware/spray equipment: Not available.

Emergency exposure: Not available.

Incompatibilities: Not available.

Behavior in Plants

Symptomology: Not available.

Absorption/translocation: Not available.

Mechanism of action: Inhibits acetolactate synthase (ALS), also called acetohydroxyacid synthase (AHAS), a key enzyme in the biosynthesis of the branched-chain amino acids isoleucine, leucine, and valine (1). Plant death results from events occurring in response to ALS inhibition, but the actual sequence of phytotoxic processes is unclear.

HRAC/ WSSA Group Designation: HRAC - B/ WSSA - 2.

Metabolism in plants: Excised shoots of canola metabolized a transpired pulse of ethametsulfuron-methyl with DT_{50} of 5-14 hours (2). Metabolism of ethametsulfuron in canola via foliage treatment involved the dealkylation of the O- and N-substituents at the triazine moiety.

Non-herbicidal biological properties: Not available.

Mechanism of resistance in weeds: Not available.

Behavior in Soil

Sorption: Not available.

Transformation: Not available.

Persistence: Not available.

Mobility: Not available.

Volatilization: Not available.

Toxicological Properties

Toxicity tests were conducted with technical grade ethametsulfuron unless otherwise indicated.

Acute toxicity

Synthesis: Not available.

Purification of technical: Not available.

Analytical methods: Not available.

Historical: Not available.

Ethametsulfuron technical: Oral LD_{50} rat >5000 mg/kg; Dermal LD_{50} rabbit >2000 mg/kg; 4-h Inhal. LC_{50} rat >5.7 mg/L; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, mild.

MUSTER: Oral LD_{50} rat >5000 mg/kg; Dermal LD_{50} rabbit >2000 mg/kg; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, none.

Subchronic toxicity

90-d dietary, rat: NOEL 5000 ppm.

90-d dietary, dog: NOEL 10,000 ppm.

Chronic toxicity

18-mo dietary, mouse: NOEL 5000 ppm; not oncogenic.

24-mo dietary, rat: NOEL 500 ppm; not oncogenic; serum sodium effects at 5000 ppm.

12-mo dietary, dog: NOEL 3000 ppm; effects on hematology parameters at 15,000 ppm.

Teratogenicity

Rat: NOEL 1000 mg/kg/d; not teratogenic; fetal weight effects at 4000 mg/kg/d.

Rabbit: NOEL 250 mg/kg/d; not teratogenic; maternal effects at 1000 mg/kg/d, and fetal effects at 4000 mg/kg/d.

Reproduction

Rat: NOEL 5000 ppm; body weight effects at 20,000 ppm.

Mutagenicity

Gene mutation: Ames test, negative; CHO, negative.

Structural chromosome aberration: *In vivo* cytogenetics, negative; Mouse micronucleus, negative.

DNA damage/repair: Rat hepatocytes/UDS, negative.

Wildlife

Ethametsulfuron technical: Bobwhite quail, oral LD_{50} >2250 mg/kg, 8-d dietary LC_{50} >5620 ppm; Mallard duck, oral LD_{50} >2250 mg/kg, 8-d dietary LC_{50} >5620 ppm; Earthworm, LC_{50} in soil >1000 mg/kg; Honey bee, LD_{50} >12.5 µg/bee; Daphnia 48-h LC_{50} >550 mg/L; Bluegill sunfish 96-h LC_{50} >600 mg/L; Rainbow trout 96-h LC_{50} >600 mg/L.

Use classification: General Use.

Synthesis and Analytical Methods

Information Sources

Primary industry source: Du Pont.

Reference

1. LaRossa and Schloss. 1984. J. Biol. Chem. 259:8753.
2. Lichtner, F. T. Dietrich, R.F. , and Brown, H. M. 1995. Pestic. Biochem. Physiol. 52: 12-24.
3. Schmuckler, M.E. et al. 2000. Pest Mangmt. Sci. 56:521-532.

FENOXAPROP

(±)-2-[4-[(6-chloro-2-benzoxazolyl)oxy]phenoxy]propanoic acid

Nomenclature

Common name: fenoxaprop (ANSI, BSI, ISO, WSSA) for the racemic mixture of *R* and *S* isomers; fenoxaprop-P (BSI, ISO) for the *R* isomer.

Manufacturers, products, and formulations

Aventis: ACCLAIM® EXTRA and WHIP® 360, 68 g fenoxaprop-P ethyl ester/L (0.57 lb ai/gal), EC; ACCLAIM; CHEYENNE®, mix of fenoxaprop-P ethyl ester + MCPA isooctyl ester (io ester) at 56 g ai/L + 259 g ae/L (0.467 lb ai/gal + 2.16 lb ae/gal) packaged with thifensulfuron + tribenuron at 50 + 25% ai, EC for fenoxaprop-P + MCPA, WG for thifensulfuron + tribenuron; DAKOTA®, mix of fenoxaprop-P ethyl ester + MCPA io ester at 28 g ai/L + 340 g ae/L (0.234 lb ai/gal + 2.84 lb ae/gal), EC; TILLER EC, mix of fenoxaprop-P ethyl ester + MCPA io ester + 2,4-D io ester at 45 g ai/L + 210 g ae/L + 69.5 g ae/L (0.375 lb ai/gal + 1.75 lb ae/gal + 0.58 lb ae/gal), EC.

Syngenta: FUSION, mix of fluazifop-P butyl ester + fenoxaprop ethyl ester at 240 + 79 g ai/L, EC.

Other names: HOE-33171; HOE-46360; fenoxaprop-ethyl = (±)-ethyl 2-[4-[(6-chloro-2-benzoxazolyl)oxy]phenoxy]propanoate; (±)-2-[4-(6-chloro-1,3-benzoxazol-2-yloxy)phenoxy]propionic acid (IUPAC); (±)-2-[4-(6-chlorobenzoxazol-2-yloxy)phenoxy]propionic acid; fenoxaprop-P = (+)-2-[4-[(6-chloro-2-benzoxazolyl)oxy]phenoxy]propanoic acid.

Chemical family: Aryloxyphenoxy propionate.

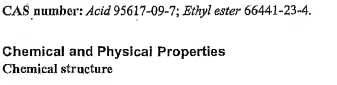
AWLN: *Acid* (56 bN dO) cOR dOY1&VQ& gG; *Ethyl ester* (56 bN dO) cOR dOY1&VO2& gG.

CAS number: *Acid* 95617-09-7; *Ethyl ester* 66441-23-4.

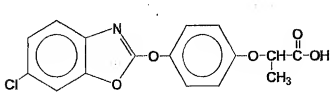
Chemical and Physical Properties

Chemical structure

Fenoxaprop acid



Fenoxaprop ethyl ester



Molecular formula: *Acid* $C_{16}H_{12}ClNO_5$; *Ethyl ester* $C_{18}H_{16}ClNO_5$.

Molecular weight: *Acid* 333.73; *Ethyl ester* 361.78.

Description: Beige to brown coarse powder, weakly aromatic.

Density: 1.3 g/mL at 20°C

Melting point: 89-91°C

Boiling point: 300°C at 0.1 mm Hg

Vapor pressure: 1.9 x 10^{-8} kPa (1.4 x 10^{-7} mm Hg) at 20°C, and 4.3 x 10^{-9} kPa (3.2 x 10^{-8} mm Hg) at 25°C.

Stability: Slowly degraded by UV light; Decomposed by acids and alkalis.

Solubility

water 0.5-1 mg/L at 20°C

organic solvents g/100 mL at 20°C:

acetone 51	ethyl acetate 24
ethanol 2	*n*-hexane 0.5

pK_a: *Acid* NAv; *Methyl ester* None.

K_{ow}: 13,200

Herbicidal Use

Fenoxaprop-P can be applied POST at 37.5-111 g ai/ha (0.0335-0.0995 lb ai/A) in soybeans, POST at 0.04-0.39 kg ai/ha (0.03-0.35 lb ai/A) in turf, POST at 32.8-91.5 g ai/ha (0.0293-0.0817 lb ai/A) in wheat, and POST at 70.4-93.8 g ai/ha (0.0628-0.0838 lb ai/A) in conservation reserve (set-aside) land. OPTION II also can be applied POST as a 0.74% v/v solution (2.25 g fenoxaprop-P ai/gal) in a spray-to-wet application in soybeans. Fenoxaprop rates are twice those of fenoxaprop-P. Fenoxaprop applied by itself is phytotoxic to wheat but has selectivity in wheat (excluding durum) when applied with certain broadleaf herbicides (2,4-D, MCPA, thifensulfuron, and tribenuron) that antagonize its activity against wheat. This antagonism-based selectivity in wheat is utilized in CHEYENNE, TILLER, and DAKOTA herbicides. Fenoxaprop controls nearly all annual and some perennial grass weeds with no injury to broadleaf species.

Use Precautions

Fire hazard: Not available.

Corrosiveness: Noncorrosive.

Storage stability: Stable for >2 yr. Do not store below -7°C (20°F).

Cleaning glassware/spray equipment: Wash with detergent or approved spray tank cleaners.

Emergency exposure: Flush eyes and skin with water for at

For symbol and abbreviation definitions, see page 453.

least 15 min. If ingested, do not induce vomiting; seek immediate medical attention.

Incompatibilities: None known.

Behavior in Plants

Symptomology: Growth ceases soon after application with young and actively growing tissues affected first. Leaf chlorosis and eventually necrosis develop within 1-3 wk of application. Leaf sheaths become brown and mushy at and just above their point of attachment to the node. Older leaves often turn purple, orange, or red before becoming necrotic.

Absorption: The ethyl ester of fenoxaprop is rapidly absorbed into leaves and appears to be rainfast within about 2 h (2). Fenoxaprop ester readily diffuses across the plasmalemma. Once inside the cell, the ester is rapidly hydrolyzed to fenoxaprop acid which remains dissociated as the anion in the relatively alkaline cytoplasm. Because of its low lipophilicity, the polar fenoxaprop anion is largely prevented from diffusing back out across the plasmalemma. Fenoxaprop ethyl ester that is deesterified before entering the cell would tend to diffuse across the plasmalemma as the protonated fenoxaprop acid (relatively lipophilic). Inside the cell, fenoxaprop acid would dissociate to the anion, thereby "trapping" the herbicide in the symplasm.

Translocation: Fenoxaprop principally is translocated in the symplasm (including the phloem). Foliar-applied fenoxaprop accumulates in meristematic regions, although translocation rates are low and only about 2% of the absorbed fenoxaprop moves out of the treated leaf.

HRAC/ WSSA Group Designation: HRAC - A/ WSSA - 1.

Mechanism of action: As with other aryloxyphepoxy propionates and with the cyclohexanedione herbicides, fenoxaprop inhibits acetyl-CoA carboxylase (ACCase), the enzyme catalyzing the first committed step in *de novo* fatty acid synthesis (3). Inhibition of fatty acid synthesis presumably blocks the production of phospholipids used in building new membranes required for cell growth. Broadleaf species are naturally resistant to aryloxyphenoxy propionate and cyclohexanedione herbicides because of an insensitive ACCase. An alternative mechanism of action has been proposed, involving destruction of the electrochemical potential of the cell membrane, but the contribution of this hypothesis remains in question.

Metabolism in plants: Fenoxaprop ethyl ester is rapidly deesterified in plants to the herbicidally-active fenoxaprop acid. Further metabolism of the herbicide appears to be considerably slower than that of other aryloxyphenoxy propionate herbicides. Fenoxaprop ethyl ester applied to wheat, barley, and crabgrass was metabolized 29, 63, and 9%, respectively, to products other than fenoxaprop acid 48 h after treatment (7). Following hydrolysis to fenoxaprop acid, the major metabolites include hydroxylated and nonhydroxylated benzoxazolone (6-chloro-2,3-dihydro-benzoxazol-2-one) and unidentified water-soluble metabolites which may be carbohydrate conjugates (6). The proportion of these major metabolites varies with species. Fenoxaprop tolerance among species generally is associated with higher rates of detoxification (4). At harvest, soybean seed were free of fenoxaprop or its metabolites.

Non-herbicidal biological properties: None known.

Mechanism of resistance in weeds: Fenoxaprop-resistant biotypes of wild oats and green foxtail have been reported, but no mechanism has yet been determined.

Behavior in Soil

Sorption

K_{oc}: Average is 9490 mL/g for fenoxaprop ethyl ester (5).

Transformation: Under aerobic or anaerobic conditions, the half-life is <1 d for conversion of fenoxaprop ethyl ester to the phytotoxic fenoxaprop acid. The acid is degraded primarily to 6-chloro-2,3-dihydrobenzoxazole-2-one and 4-(6-chloro-2-benzoxazolyloxy)phenol.

Persistence: Typical half-life is 9 d (5-14 d depending on soil type) under aerobic and 30 d under anaerobic conditions.

Mobility: Low mobility in two silt loam soils and one silty clay soil. Residues have not been detected below 15 cm in soil. Aged residues of fenoxaprop also show no leaching potential.

Volatilization: Negligible losses.

Toxicological Properties

Toxicity tests were conducted with technical grade fenoxaprop ethyl ester unless otherwise indicated.

Acute toxicity

Fenoxaprop ethyl ester technical: Oral LD_{50} male rat 3310 mg/kg, female rat 3400 mg/kg; Dermal LD_{50} male rabbit >2000 mg/kg; 4-h Inhal. LC_{50} rat 3.92 mg/L; Skin irrit. rabbit, slight; Skin sensitiz., NAv; Eye irrit. rabbit, moderate.

Subchronic toxicity

90-d dietary, rat: NOEL 80 mg/kg/d.

90-d dietary, dog: NOEL 16 mg/kg/d.

Chronic toxicity: Not available.

Teratogenicity: Not available.

Reproduction: Not available.

Mutagenicity: Not available.

Wildlife

Fenoxaprop ethyl ester technical: Bobwhite quail oral LD_{50} >2510 mg/kg; Honey bee oral LD_{50} >0.02 µg/bee; Daphnia 48-h LC_{50} 11.15 mg/L; Bluegill sunfish 96-h LC_{50} 3.34 mg/L.

Use classification: General Use for most products; Restricted Use for OPTION II and BUGLE because of eye irritation.

Synthesis and Analytical Methods

Synthesis: Not available.

For symbol and abbreviation definitions, see page 453.

Purification of technical: Not available.

Analytical methods: Details of HPLC methods are available from Aventis.

Historical: First reported in 1982 (1). Fenoxaprop ethyl ester was introduced by Hoechst AG.

Information Sources

Primary industry source: Aventis.

References

1. Bieringer, H. et al. 1982. Proc. Br. Crop Prot. Conf.-Weeds 1:11.
2. Bryson, C. T. 1988. Weed Technol. 2:153.
3. Kobek, K. et al. 1988. Z. Naturforsch. 43c:47.
4. Lefsrud and Hall. 1989. Pestic. Biochem. Physiol. 34:218.
5. Wauchope, R. D. et al. 1992. Rev. Environ. Contam. Toxicol. 123:1.
6. Wink, O. et al. 1984. J. Agric. Food Chem. 32:187.
7. Yaacoby, T. et al. 1991. Pestic. Biochem. Physiol. 41:296.

FENTRAZAMIDE

4-(2-chlorophenyl)-5-oxo-4,5-dihydro-tetrazole-1-carboxylic acid cyclohexyl-ethyl-amide

Nomenclature

Common name: Fentrazamide (ISO).

Manufacturers, products, and formulations

Bayer: LECS®, 6.75%, WP; LECSPRO, a mix of fentrazamide + propanil at 6.75 + 37.5%, WP (outside US).

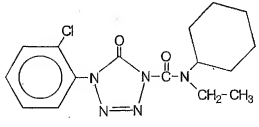
Other names: BAY YRC 2388 (code name); NBA 061 (code name in Japan).

Chemical family: Tetrazolinone.

CAS number: 158237-07-1

Chemical and Physical Properties

Chemical structure:



Molecular formula: $C_{16}H_{20}ClN_5O_2$

Molecular weight: 349.82

Description: Colorless crystals.

Density: 1.30 g/mL at 20 C

Melting point: 79°C

Boiling point: Not measurable due to thermal decomposition.

Vapor pressure: 5 x 10^{-10} hPa at 20°C

Stability: stable.

Solubility:

water 2.3 mg/L at 20°C
organic solvents g/L at 20 C:
2-propanol - 32
xylene - >250

pK_a: Does not dissociate.

K_{ow}: logP 3.60 at 20 C.

Herbicdal Use

Fentrazamide is under development for the control of barnyardgrass and annual sedges in rice (1). Fentrazamide at 200 to 300 g ai/ha has shown excellent efficacy against barnyardgrass within a wide range of growth stages from PRE up to 3 leaf stage of the weed with good compatibility to rice. Combinations of fentrazamide with sulfonylurea herbicides such as bensulfuron-methyl, cyclosulfamuron and imazosulfuron provide excellent broadleaf weed control that covers the entire weed spectrum of transplanted rice grown in Japan.

Use Precautions

Fire hazard: Fentrazamide is not flammable.

Corrosiveness: Product is non-corrosive.

Storage stability: Technical active ingredient is not sensitive to oxidizing or reducing agents.

Cleaning glassware/spray equipment: Wash equipment and glassware with water and detergent.

For symbol and abbreviation definitions, see page 453.

FLUAZIFOP-P-BUTYL

(*R*)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid

Nomenclature

Common name: fluazifop-P (ANSI, BSI, ISO, WSSA) for the *R* isomer; fluazifop (ANSI, BSI, ISO, WSSA) for the racemic mixture of *R* and *S* isomers.

Manufacturers, products, and formulations

Aventis: HORIZON 2000, mix of fluazifop-P butyl ester + fenoxaprop ethyl ester at 240 + 79 g ai/L (2 + 0.66 lb ai/gal), EC.

PBI/Gordon: ORNAMEC OVER THE TOP, 60 g ai/L (0.5 lb ai/gal), butyl ester, EC; ORNAMEC 170, 15 g ai/L (0.125 lb ai/gal), butyl ester, EC.

Syngenta: FUSILADE DX, 240 g ai/L, butyl ester, EC; FUSION, mix of fluazifop-P butyl ester + fenoxaprop ethyl ester at 240 + 79 g ai/L, EC; TORNADO®, mix of fomesafen Na salt + fluazifop-P butyl ester at 120 + 90 g ai/L (1 + 0.75 lb ai/gal), EC.

Other names: Fluazifop-P-butyl; IH773B; ICIA005; ICIA009; PP005; PP009; TF1169; (*R*)-2-[4-(5-trifluoromethyl-2-pyridyloxy)phenoxy]propionate.

Chemical family: Aryloxyphenoxy propionate.

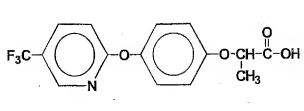
AWLN: *Acid* (6N) bOR doY1&VQ& eXFFF &R(+) Form; *Butyl ester* (6N) bOR dOY1&VO4& eXFFF &R(+) Form.

CAS number: *Acid* 83066-88-0; *Butyl ester* 69335-91-7.

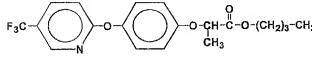
Chemical and Physical Properties

Chemical structure

Fluazifop-P acid



Fluazifop-P butyl ester



Molecular formula: *Acid* $C_{15}H_{12}F_3NO_4$; *Butyl ester* $C_{19}H_{20}F_3NO_4$.

Molecular weight: *Acid* 327.26; *Butyl ester* 383.37.

Description: Light straw-colored liquid, odorless.

Density: 1.22 g/mL at 20°C

Melting point: 10°C

Boiling point: No boiling point at atmospheric pressure.

Vapor pressure: 3.3 x 10-8 kPa (2.5 x 10^{-7} mm Hg) at 20°C for fluazifop-P butyl ester, and 5.5 x 10-8 kPa (4.1 x 10^{-7} mm Hg) at 20°C for fluazifop butyl ester.

Stability: Stable to UV light.

Solubility

water 1.1 mg/L at 25°C
organic solvents:
miscible in acetone, chloroform, cyclohexanone, dichloromethane, ethyl acetate, *n*-hexane, methanol, methylene chloride, methylene dichloride, toluene, and xylene.

pK_a: *Acid* 2.98 at 20°C; *Butyl ester* None.

K_{ow}: 1200 at pH 2.6 and 20°C, and 0.8 at pH 7 and 20°C.

Herbicidal Use

Fluazifop-P can be applied POST at 0.053-0.21 kg ai/ha (0.047-0.188 lb ai/A) in cotton, soybeans, stone fruits, asparagus, carrots, garlic, coffee, endive, pecans, rhubarb, and tabasco peppers. It controls most annual and perennial grass weeds including barnyardgrass, crabgrass spp., downy brome, *Panicum* spp., foxtail spp., volunteer cereals, shattercane, quackgrass, and johnsongrass. Fluazifop-P has essentially no activity on broadleaf species. An oil adjuvant or nonionic surfactant is required for maximum efficacy.

Use Precautions

Fire hazard: FUSILADE DX is nonflammable. Fluazifop-P technical is nonflammable; flash point is 41.78°C (107°F).

Corrosiveness: Noncorrosive under normal conditions.

Storage stability: Stable for >4 mo at 50°C (122°F), >7 mo at 37°C (99°F), and >16 mo at 5 and 20°C (41 and 68°F).

Cleaning glassware/spray equipment: Clean sprayers with water plus either a commercial tank cleaner or surfactant.

Emergency exposure: Slightly irritates eyes.

Incompatibilities: Antagonism of grass control has been observed when fluazifop-P has been mixed with certain

For symbol and abbreviation definitions, see page 453.

broadleaf herbicides. Incompatible with strong oxidizing agents.

Behavior in Plants

Symptomology: Growth ceases soon after application with young and actively growing tissues affected first. Leaf chlorosis and eventually necrosis develop 1-3 wk after application. Leaf sheaths become brown and mushy at and just above their point of attachment to the node. Older leaves often turn purple, orange, or red before becoming necrotic.

Absorption: The butyl ester of fluazifop-P is rapidly absorbed into leaves and is rainfast within about 2 h of application (1). Fluazifop-P butyl ester presumably diffuses readily across the plasmalemma. Once inside the cell, the herbicide is rapidly deesterified to fluazifop acid which dissociates in the relatively alkaline cytoplasm. The dissociated anion is "trapped" inside the cell due to its inability to traverse the plasmalemma, a consequence of its negative charge and low lipophilicity. If fluazifop butyl ester is hydrolyzed outside the cell, the relatively acid environment allows a significant proportion of fluazifop acid to remain in the protonated (undissociated) form which readily diffuses across the plasmalemma and into the cell. Upon entering the alkaline cytoplasm, the acid dissociates and is trapped inside. Thus, the "ion trapping" principles facilitate a build-up of fluazifop in the symplasm.

Translocation: Fluazifop-P butyl principally translocates in the symplasm (including the phloem) and accumulates in meristematic regions of the root and shoot. Translocation rate appears to be slow, however.

Mechanism of action: As with other aryloxyphenoxy propionates and with the cyclohexanedione herbicides, fluazifop-P inhibits acetyl-CoA carboxylase (ACCase), the enzyme catalyzing the first committed step in *de novo* fatty acid synthesis (2, 4). Inhibition of fatty acid synthesis presumably blocks the production of phospholipids used in building new membranes required for cell growth. Broadleaf species are naturally resistant to aryloxyphenoxy propionate and cyclohexanedione herbicides because of an insensitive ACCase. An alternative mechanism of action has been proposed, involving destruction of the electrochemical potential of the cell membrane, but the contribution of this hypothesis remains in question.

HRAC/ WSSA Group Designation: HRAC - A/ WSSA - 1.

Metabolism in plants: Fluazifop-P butyl ester is hydrolyzed rapidly in plants to the phytotoxic fluazifop-P acid. Quackgrass (fluazifop susceptible) retained 46-79% of applied fluazifop as the acid after 48 h, whereas a small fraction was metabolized to polar and nonpolar conjugates (3).

Non-herbicidal biological properties: Sublethal rates may suppress seed head development in some grass species, such as red rice and downy brome (6, 7). At very low rates, 0.014 kg ai/ha (0.0125 lb ai/A), fluazifop-P retards grass growth. Activity as a sugarcane ripener also has been reported.

Mechanism of resistance in weeds: Most fluazifop-P-resistant biotypes appear to have an ACCase that is insensitive to the herbicide. However, in diclofop-resistant rigid ryegrass from Australia, cross-resistance to a number of herbicides including fluazifop is not due to differential ACCase sensitivity (5). Rather, resistance may be due to increased herbicide metabolism or by sequestration away from the site of action.

Behavior in Soil

Sorption

K_{oc}: Average is 5700 mL/g for the butyl ester (8).

Transformation

Photodegradation: Negligible losses.

Other degradation: Fluazifop-P butyl ester is rapidly (half-life of <1 wk) deesterified in moist soils to the acid which has a half life of ~3 wk under moist conditions in most soils.

Persistence: Average field half-life is 15 d (8). Fluazifop-P occasionally controls or suppresses grass weeds germinating after application. Degree of residual activity varies with soil type and rainfall. Susceptible rotational crops can be planted 60 d after fluazifop-P application.

Mobility: Fluazifop-P butyl ester has low mobility in soil, while fluazifop-P acid is somewhat more mobile. Neither chemical presents an appreciable risk of groundwater contamination.

Volatilization: Negligible losses.

Toxicological Properties

Toxicity tests were conducted with technical grade fluazifop-P butyl ester unless otherwise indicated.

Acute toxicity

Fluazifop-P butyl ester technical: Oral LD_{50} male rat 4096 mg/kg, female rat 2721 mg/kg; Dermal LD_{50} rabbit >2420 mg/kg; 4-h Inhal. LC_{50} NAv; Skin irrit. rabbit, slight; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, mild.

FUSILADE DX: Oral LD_{50} male rat >5000 mg/kg, female rat 5690 mg/kg; Dermal LD_{50} rabbit >2000 mg/kg; 4-h Inhal. LC_{50} male rat >0.54 mg/L, female rat >0.77 mg/L; Skin irrit. rabbit, moderate; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, mild.

Subchronic toxicity

90-d dietary, rat: NOEL 10 mg/kg/d.

Chronic toxicity: Not available.

Teratogenicity: Not available.

Reproduction: Not available.

For symbol and abbreviation definitions, see page 453.

Mutagenicity: Not available.

Wildlife

Fluazifop-P butyl ester technical: Bobwhite quail 5-d dietary LC_{50} >4659 ppm; Mallard duck, oral LD_{50} >3528 mg/kg, 5-d dietary LC_{50} >4321 ppm; Honey bee, oral LD_{50} >100 µg/bee, topical LD_{50} >240 µg/bee; Daphnia 48-h LC_{50} >10 mg/L; Bluegill sunfish 96-h LC_{50} 0.53 mg/L; Rainbow trout 96-h LC_{50} 1.37 mg/L.

Use classification: General Use for all products.

Synthesis and Analytical Methods

Synthesis: Several methods can be used, including reaction of 4-(5-trifluoromethyl-2-pyridyloxy)-phenol with butyl 2-chloropropionate and base.

Purification of technical: Not available.

Analytical methods: GLC methods are used for analysis of the technical, derivatives, and formulated products. Residue methods are available for certain crops (see AOAC Methods, 1984, 6.353-6.357; CIPAC Handbook, 1988, ID, 106).

Historical: Discovered by Ishihara Sangyo Kaishi, Ltd., and developed jointly with ICI Plant Protection Division (now Zeneca). Great Britain patent 1,599,121 was awarded to Ishihara. Fluazifop-P was first tested for herbicidal activity by ICI Americas in the U.S. in 1981.

Information Sources

Primary industry source: Syngenta.

References

1. Bryson, C. T. 1988. Weed Technol. 2:153.
2. Burton, J. D. et al. 1989. Pestic. Biochem. Physiol. 34:76.
3. Coupland, D. 1985. Proc. Brit. Crop Prot. Conf.-Weeds, p. 317.
4. Kobek, K. et al. 1988. Z. Naturforsch. 43c:47.
5. Powles, S. B. et al. 1990. Pages 394-406 *in* M. B. Green, H. M. LeBaron, and W. K. Moberg, eds., Managing Resistance to Agrochemicals. Am. Chem. Soc. Symp. Ser. 421, Washington, DC.
6. Richardson, J. M. et al. 1987. Weed Sci. 35:277.
7. Salzman, F. P. et al. 1988. Weed Sci. 36:800.
8. Wauchope, R. D. et al. 1992. Rev. Environ. Contam. Toxicol. 123:1.

For symbol and abbreviation definitions, see page 453.

HALOSULFURON technical: Bobwhite quail, oral LD_{50} >2250 mg/kg, 5-d dietary LC_{50} >5620 ppm, 1-generation reproduction NOEC 1000 ppm; Mallard duck, 8-d dietary LC_{50} >5620 ppm, 1-generation reproduction NOEC 1000 ppm; Honey bee topical LD_{50} >100 µg/bee; Daphnia 48-h LC_{50} >107 mg/L; Bluegill sunfish 96-h LC_{50} >118 mg/L; Rainbow trout 96-h LC_{50} >131 mg/L; Sheepshead minnow 96-h LC_{50} >125 mg/L; Mysid shrimp 96-h LC_{50} 109 mg/L; Oyster 96-h shell deposition EC_{50} 94 mg/L; Selenastrum EC_{50} 0.0053 mg/L.

Use classification: General Use.

Synthesis and Analytical Methods

Synthesis: Not available.

Purification of technical: Not available.

Analytical methods: Not available.

Historical: Synthesized and discovered by Nissan Chemical Industries, Ltd. of Tokyo, Japan. Introduced at the Brighton Centre Nov. 19, 1991. Commercial products are being developed in the U.S. by Monsanto.

Information Sources

Primary industry source: Monsanto.

References

1. Gustafson, D. I. 1989. Environ. Toxicol. Chem. 8:339.
2. LaRossa and Schloss. 1984. J. Biol. Chem. 259:8753.

HALOXYFOP

(±)-2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid

Nomenclature

Common name: haloxyfop (ANSI, ISO, WSSA) for the racemic mixture of *R* and *S* isomers; haloxyfop-P for the *R* isomer.

Manufacturers, products, and formulations

Dow AgroSciences: GALANT™ Herbicide (S. America), GALANT EC (Bolivia), GALANT 240 (Colombia), GALLANT™ 240 Herbicide (Taiwan and Thailand), and VERDICT™ Herbicide (Uruguay), 240 g ai/L (2 lb ai/gal), methyl ester, EC; VERDICT EC, 25.8% ai, methyl ester, EC (Brazil); GALANT 75 (Colombia) and VERDICT AC (Colombia and Peru), 75 g ai/L (0.626 lb ai/gal), methyl ester, EC; VERDICT 104 (Australia) and GALLANT (New Zealand), 104 g ai/L (0.868 lb ai/gal), methyl ester, EC; GALANT LPU (Argentina) and GALANT PLUS (Chile), 60 g ai/L (0.5 lb ai/gal), methyl ester, EC; GALANT PLUS R (Chile) and DE 535™ EC Herbicide (China), 30 g ai/L (0.25 lb ai/gal), haloxyfop-P methyl ester, EC; VERDICT R (Colombia), 40 g ai/L (0.33 lb ai/gal), haloxyfop-P methyl ester, EC; GALANT R (Argentina), 120 g ai/L (1 lb ai/gal), haloxyfop-P methyl ester, EC; MIRAGE™ Herbicide (Argentina), GALLANT SUPER (E. Europe and Turkey), GALLANT 10.8 E (China), ELOGE™ Herbicide (France), PERENAL™ Herbicide (Hungary and Poland), GALANT PLUS (Spain), and GALLANT 535 (Switzerland), 104 g ai/L, haloxyfop-P methyl ester, EC; VERDICT DF (Australia), 26% ai, haloxyfop-P methyl ester, WG; and GALLANT 125 (Europe, Asia, and Middle East), ZELLECK™ Herbicide (C.I.S.), and GALANT 125

(Africa and Europe), 125 g ai/L (1.04 lb ai/gal), haloxyfop-P methyl ester, EC.

Other names: DOWCO 453 ME; haloxyfop-methyl = methyl 2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate; (*RS*)-2-[4-(3-chloro-5-trifluoromethyl-2-pyridyloxy)phenoxy]propionic acid (IUPAC). Not registered in U.S.

Chemical family: Aryloxyphenoxy propionate.

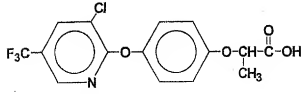
AWLN: *Acid* (6N) bOR dOY1&VQ& cG eXFFF; *Ethoxyethyl ester* (6N) bOR dOY1&VO2O2& cG eXFFF; *Methyl ester* (6N) bOR dOY1&VO1& cG eXFFF.

CAS number: *Acid* 69806-34-4 for *R* and *S* isomeric mixture; *Ethoxyethyl ester* 87237-48-7 for *R* and *S* isomeric mixture; *Methyl ester* 69806-40-2 for *R* and *S* isomeric mixture.

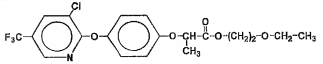
Chemical and Physical Properties

Chemical structure

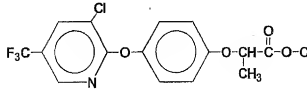
Haloxyfop acid



Haloxyfop ethoxyethyl ester (etotyl ester)



Haloxyfop methyl ester



Molecular formula: *Acid* $C_{15}H_{11}ClF_3NO_4$; *Ethoxyethyl ester* $C_{19}H_{19}ClF_3NO_5$; *Methyl ester* $C_{16}H_{13}ClF_3NO_4$.

Molecular weight: *Acid* 361.70; *Ethoxyethyl ester* 433.81; *Methyl ester* 375.73.

Description: *Acid* White crystal, offensive odor; *Ethoxyethyl ester* Yellow-orange solid, mild aromatic odor; *Methyl ester* Amber to straw yellow solid, mild aromatic odor.

Density: *Ethoxyethyl ester* 0.978 g/mL; *Methyl ester* 0.968 g/mL.

Melting point: *Acid* 107-108°C; *Ethoxyethyl ester* 56-58°C; *Methyl ester* 55-57°C.

Boiling point: Unknown.

Vapor pressure: *Acid* <1.7 x 10^{-8} kPa (<1.3 x 10^{-7} mm Hg)at 25°C; *Ethoxyethyl ester* 4.5 x 10^{-7} kPa (3.4 x 10^{-6} mm Hg) at 25°C; *Methyl ester* 8.67 x 10^{-8} kPa (6.5 x 10^{-7} mm Hg) at 25°C.

Stability: *Methyl ester* Stable to UV light; No decomposition after 88 h at 200°C.

Solubility

Acid

water 43.3 mg/L at 25°C and pH 7

organic solvents g/100 mL at 25°C:

acetone >100 (20°C)	methanol >100 (20°C)
dichloromethane 45.9	propan-2-ol >100 (20°C)
ethyl acetate 51.8	toluene 11.8
n-hexane 0.017	xylene 7.4 (20°C)

Ethoxyethyl ester

water 0.58 mg/L at 20°C

organic solvents g/100 mL at 20°C:

acetone >100	methylene chloride 276
dichloromethane >100	propan-2-ol 5.2
ethyl acetate >100	toluene >100
n-hexane 4.4	xylene 125
methanol 23.3	

Methyl ester

water 9.3 mg/L at 25°C

organic solvents g/100 mL at 20°C:

acetone 355	methylene chloride 300
acetonitrile 400	xylene 127
isopar M 1.3	

pK_a: 4.33

K_{oc}: *Acid* 22 at 20°C; *Ethoxyethyl ester* 21,600; *Methyl ester* 11,700.

Herbicidal Use

Haloxyfop can be applied POST at 0.14-0.6 kg ae/ha in cotton, soybeans, sunflowers, sugarbeets, oilseed rape, potatoes, field beans, peas, flax, oil palm, peanuts, vine crops, and certain other minor crops. It controls annual and perennial grasses with the higher rates needed for perennials. Major susceptible species include foxtail spp., barnyardgrass, crabgrass spp., *Panicum* spp., *Brachiaria* spp., bluegrass spp., goosegrass, blackgrass, wild oats, quackgrass, shattercane, johnsongrass, bermudagrass, woolly cupgrass, sprangletop, and *Lolium* spp. Rates of haloxyfop-P are about one-half those of haloxyfop. A surfactant or oil adjuvant is required for maximum efficacy, although certain commercial formulations already contain sufficient adjuvant.

Use Precautions

Fire hazard: Technical is nonflammable. VERDICT is nonflammable; flash point is 43°C (109°F); GALLANT and ZELLECK are nonflammable; flash points are 47°C (117°F).

Corrosiveness: Haloxyfop acid is noncorrosive.

Storage stability: Haloxyfop acid is stable for >6 mo at 38°C.

For symbol and abbreviation definitions, see page 453.

Formulated products have >2 yr shelf life at room temperature.

Cleaning glassware/spray equipment: Rinse equipment with soap and water.

Emergency exposure: Wash skin with soap and water. Flush eyes with water for at least 5 min; get medical attention if irritation persists. If ingested, drink 1-2 glasses of water and induce vomiting; call a physician.

Incompatibilities: Haloxyfop can be antagonized by certain herbicides, especially those producing rapid leaf necrosis.

Behavior in Plants

Symptomology: Growth ceases soon after application with young and actively growing tissues affected first. Leaf chlorosis and eventually necrosis develop within 1-3 wk of application. Leaf sheaths become brown and mushy at and just above their point of attachment to the node. Older leaves often turn purple, orange, or red before becoming necrotic.

Absorption: Haloxyfop methyl ester is absorbed rapidly into leaves and appears to be rainfast within about 2 h (1). Haloxyfop ester readily diffuses across the plasmalemma. Once inside the cell, the ester is rapidly hydrolyzed to haloxyfop acid which remains dissociated as the anion in the relatively alkaline cytoplasm. Because of its low lipophilicity, the polar haloxyfop anion is largely prevented from diffusing back out across the plasmalemma. Haloxyfop methyl ester that is deesterified before entering the cell would tend to diffuse across the plasmalemma as the protonated haloxyfop acid (relatively lipophilic). Inside the cell, haloxyfop acid would dissociate to the anion, thereby "trapping" the herbicide in the symplasm.

Translocation: Haloxyfop principally is translocated in the symplasm (including the phloem). Foliar-applied haloxyfop accumulates in meristematic regions. Translocation rates are low in some species but faster in others (2).

Mechanism of action: As with other aryloxyphenoxy propionates and with the cyclohexanedione herbicides, haloxyfop inhibits acetyl-CoA carboxylase (ACCase), the enzyme catalyzing the first committed step in *de novo* fatty acid synthesis (3, 6). Inhibition of fatty acid synthesis presumably blocks the production of triglycerides used in building new membranes required for cell growth. Broadleaf species are naturally resistant to aryloxyphenoxy propionate and cyclohexanedione herbicides because of an insensitive ACCase. Similarly, natural tolerance of red fescue to haloxyfop and sethoxydim appears to be due to a less sensitive ACCase (7). An alternative mechanism of action has been proposed, involving destruction of the electrochemical potential of the cell membrane, but the contribution of this hypothesis remains in question.

HRAC/WSSA Group Designation: HRAC - A/ WSSA - 1.

Metabolism in plants: Haloxyfop methyl ester is hydrolyzed rapidly in tolerant and susceptible plants to the herbicidally active haloxyfop acid. Five h after corn leaves were treated with haloxyfop methyl ester, 50% of the applied was recovered as haloxyfop acid, 31% as unmetabolized haloxyfop methyl ester, and 19% as unidentified polar metabolites thought to be conjugated forms of the herbicide (4). Rates of deesterification and subsequent metabolism to polar products vary among grass species, and may account for differential susceptibility to the herbicide (2).

Non-herbicidal biological properties: None known.

Mechanism of resistance in weeds: Haloxyfop resistance in biotypes of normally sensitive grass weeds, including *Lolium multiflorum* (selected by diclofop use), has been associated with an insensitive ACCase. However, in diclofop-resistant rigid ryegrass (*L. rigidum*) from Australia, resistance to haloxyfop as well as cross-resistance to herbicides from other chemical families is not due to reduced ACCase sensitivity, but may be conferred by increased rates of herbicide metabolism (5) or by sequestration away from the site of action.

Behavior in Soil

Sorption: Moderately adsorbed to soil.

K_{oc}: 47-76 mL/g at pH 7.2-7.3 and 2.3-2.9% OM for sorption of haloxyfop acid, but 54-186 mL/g for desorption indicating that binding affinity increases with time. The metabolite, TFP (3-chloro-5-trifluoromethyl-pyridin-2-ol), had an average K_{oc} of 33 mL/g in loam-sandy soil at pH 6.5-3.2.

K_d: 0.5-2.0 mL/kg for haloxyfop acid at pH 7.2-7.3 and 2.3-2.9% OM.

K_f: Not available for haloxyfop. The metabolite, TFP, had an average K_f of 2.02 mL/g in loam-sandy soil at pH 6.5-3.2.

Transformation

Photodegradation: Negligible losses for haloxyfop methyl ester on dry soil surfaces, but slow degradation (half-life is 62 d) in the presence of moisture. Photodegradation reactions include cleavage of the aryl ether linkage and opening of the phenyl ring.

Other degradation: Haloxyfop methyl ester rapidly hydrolyzes to the acid. Further degradation produces pyridinol and phenol under aerobic conditions. No degradation occurs under anaerobic conditions.

Persistence: Moderately persistent with a typical half-life of 2-3 mo under various field conditions. Residues decline with roughly first-order kinetics. Grass crops can be planted 20-100 d after haloxyfop application, depending on crop.

Lab experiments: Half-life of 19.5 d when incubated in aerobic soils at 20°C and 40% of maximum water holding capacity.

Mobility: Haloxyfop acid is moderately mobile, but the methyl ester is estimated to be non-mobile. No residues have been detected below the plow layer in field studies. The metabolite, TFP, appears to be moderately mobile. Ground and surface water contamination with haloxyfop and TFP is unlikely except under extreme conditions of low temperature and high rainfall.

For symbol and abbreviation definitions, see page 453.

Volatilization: Negligible losses.

Toxicological Properties

Toxicity tests were conducted with technical grade haloxyfop acid unless otherwise indicated.

Acute toxicity

Haloxyfop acid technical: Oral LD_{50} male rat 337 mg/kg, female rat 545 mg/kg; Dermal LD_{50} rabbit >5000 mg/kg; 4-h Inhal. LC_{50} NAv; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, moderate.

Haloxyfop ethoxyethyl ester technical: Oral LD_{50} rat 518 mg/kg; Dermal LD_{50} rabbit >5000 mg/kg, rat >2000 mg/kg; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, moderate.

Haloxyfop methyl ester technical: Oral LD_{50} male rat 300 mg/kg, female rat 623 mg/kg; Dermal LD_{50} rabbit >2000 mg/kg; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, slight.

Subchronic toxicity

90-d dietary, mouse: NOEL 0.2 mg/kg/d; hepatocellular hypertrophy associated with peroxisome proliferation at 2 mg/kg/d.

90-d dietary, rat: NOEL 0.2 mg/kg/d; hepatocellular hypertrophy associated with peroxisome proliferation and increased pigment in renal epithelial cells at 2 mg/kg/d.

90-d dietary, dog: NOEL 2 mg/kg/d; hepatocellular hypertrophy not associated with peroxisome proliferation, decreased serum cholesterol and red blood cell count at 20 mg/kg/d.

90-d dietary, monkey: NOEL 2 mg/kg/d; hepatocellular hypertrophy not associated with peroxisome proliferation, decreased serum cholesterol and triglyceride at 30 mg/kg/d.

Chronic toxicity

18-mo dietary, mouse: NOEL 0.065 mg/kg/d; increased eosinophilic staining of hepatocytes and increased hepatocellular carcinomas associated with peroxisome proliferation at 0.6 mg/kg/d.

24-mo dietary, rat: NOEL 0.065 mg/kg/d; increased eosinophilia of hepatocytes and increased pigment in renal tubular epithelium at 0.1 mg/kg/d.

12-mo dietary, dog: NOEL 0.5 mg/kg/d; decreased serum cholesterol at 5 mg/kg/d.

Teratogenicity

Rat: NOEL 7.5 mg/kg/d; not teratogenic.

Rabbit: NOEL 20 mg/kg/d; not teratogenic.

Reproduction

Rat: NOEL 1 mg/kg/d; not a reproductive toxin.

Mutagenicity

Gene mutation: Ames test, negative; CHO/HGPRT, negative.

Structural chromosome aberration: Mouse micronucleus, negative; Human lymphocyte/cytogenetics, negative.

DNA damage/repair: Rat hepatocyte/UDS, negative.

Wildlife

Haloxyfop acid technical: Bobwhite quail 8-d dietary LC_{50} >5620 ppm; Mallard duck, oral LD_{50} >2150 mg/kg, 8-d dietary LC_{50} >5620 ppm; Daphnia 48-h LC_{50} 96.4 mg/L; Bluegill sunfish 96-h LC_{50} 548 mg/L; Rainbow trout 96-h LC_{50} 0.4 mg/L; Fathead minnow 96-h LC_{50} 0.5 mg/L.

Haloxyfop ethoxyethyl ester technical: Bobwhite quail 8-d dietary LC_{50} >5620 ppm; Mallard duck, oral LD_{50} >2150 mg/kg, 8-d dietary LC_{50} >5620 ppm; Rainbow trout 96-h LC_{50} 1.18 mg/L.

Haloxyfop methyl ester technical: Bobwhite quail, oral LD_{50} 1159 mg/kg, 8-d dietary LC_{50} >5620 ppm; Mallard duck, oral LD_{50} >2150 mg/kg, 8-d dietary LC_{50} >5620 ppm; Honey bee oral LD_{50} >100 µg/bee; Daphnia 48-h LC_{50} 6.2 mg/L; Bluegill sunfish 96-h LC_{50} 0.3 mg/L; Rainbow trout 96-h LC_{50} >50 mg/L; Fathead minnow 96-h LC_{50} 0.3 mg/L.

Use classification: General Use.

Synthesis and Analytical Methods

Synthesis: To produce haloxyfop methyl ester, the dianion form of hydroquinone is generated from hydroquinone plus two equivalents of a strong base such as sodium hydroxide in a polar aprotic solvent such as dimethylsulfoxide. The hydroquinone dianion salt is then reacted with 2,3-dichloro-5-(trifluoromethyl)pyridine at 80-90°C to give (3-chloro-5-(trifluromethyl)pyridinyl-2-oxyphenol, as the phenate salt. To the intermediate pyridinyloxyphenate at 25-30°C is added methyl 2-halopropionate to provide the product. U.S. patent 4,275,212 for the synthesis was issued in 1981.

Purification of technical: The methyl ester can be isolated by the addition of water to the reaction mixture, followed by extraction of the product into perchloroethylene. The perchloroethylene/product solution is then extracted with water to remove residual dimethylsulfoxide solvent and salts. Removal of the perchloroethylene by distillation under reduced pressure yields the methyl ester product. The methyl ester also can be isolated by a sequence involving vacuum distillation of the reaction mixture to remove the dimethylsulfoxide solvent, followed by filtration of the salts, and finally a high temperature, vacuum distillation of the product.

Analytical methods: Haloxyfop and its conjugates can be extracted from crops, grains, and soil (no conjugates produced in soil) using 0.1 M sodium chloride in 2% water/98% methanol with overnight shaking. Haloxyfop acid is partitioned from aqueous solution into toluene, adsorbed onto silica gel, and eluted with 1% acetic acid/methylene chloride, which is evaporated before methylation with BF_3 methanol. Then the methyl ester is partitioned from aqueous solution into isooctane, adsorbed onto silica gel, eluted with toluene, and then quantified by GC on OC-17/DB-17 using electron capture detection at LOQ of 0.01 ppm. See method ACR 83.1R and supplements, of The Dow Chemical Company. The haloxyfop soil metabolite, 3-chloro-5-(trifluoromethyl)-2-pyridinol, can be extracted from soil using 0.1 M sodium chloride in 2% water/98% methanol with overnight shaking.

For symbol and abbreviation definitions, see page 453.

The pyridinol is partitioned into ether, exchanged into acidified water, isolated by reverse-phase chromatography, transferred into toluene, converted to the trimethylsilyl derivative with BSA, and then quantified by GC on OV-17/DB-17 using electron capture detection at LOQ of 0.05 ppm. See method ACR 84.5 of The Dow Chemical Company.

Historical: Haloxyfop was discovered in 1976 and patented June 28, 1988; U.S. patent 4,753,673 was awarded to The Dow Chemical Company. It was first marketed in Argentina in 1986 as GALLANT. Currently it is marketed in over 30 countries under trade names of VERDICT, GALLANT, FOCUS®, and others but is not marketed in the U.S.

Information Sources

Primary industry source: Dow AgroSciences LLC, 9330 Zionsville Road, Indianopolis, IN 46268-1054.

References

1. Bryson, C. T. 1988. Weed Sci. 35:115.
2. Buhler, D. D. et al. 1985. Weed Sci. 33:291.
3. Burton, J. D. et al. 1989. Pestic. Biochem. Physiol. 34:76.
4. Harrison and Wax. 1986. Weed Sci. 34:185.
5. Powles, S. B. et al. 1990. Pages 394-406 *in* M. B. Green, H. M. LeBaron, and W. K. Moberg, eds., Managing Resistance to Agrochemicals. Am. Chem. Soc. Symp. Ser. 421, Washington, D.C.
6. Secor and Cseke. 1988. Plant Physiol. 86:10.
7. Stoltenberg, D. E. et al. 1989. Weed. Sci. 37:512.

For symbol and abbreviation definitions, see page 453.

PROPAQUIZAFOP

2-(4-aryloxyphenoxy) propionic acid

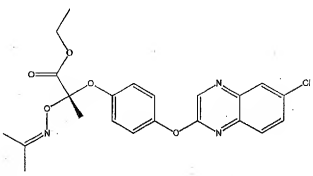
NOMENCLATURE

Common name: propaquizafop (R-isomer) (ISO)

Manufacturers:
Feinchemie: AGIL®, 100 g ai/L (Germany).
Kwizda: AGIL®, 100 g ai/L (Austria).
Syngenta: SHOGUN®, 100 g ai/L, EC (Brazil).
Other names: Agil, Shogun; 2-isopropylideneamino-oxyethyl (R)-2-[4-(6-chloroquinoxalin-2-yloxy) phenoxy] propionate.
Chemical family: aryphenoxypropianates
CAS: 111479-05-1

Chemical and Physical Properties

Chemical structure:



Molecular formula: $C_{22}H_{22}ClN_3O_5$
Molecular weight: 443.9
Description: clear yellow liquid
Density: 1.3
Boiling point: Not available.
Melting point: 66.3 C
Vapor Pressure: 4.4 x 10^{-7} Pa (25°C)
Stability: stable >2 y in closed container at room temperature. Moderately stable at acid and neutral pH. Rapidly hydrolyzed under alkaline conditions. Stable to ultraviolet light.
Solubility (25°C): 0.63 mg/l in water, 59 mg/l in ethanol, 730 mg/l in acetone, 630 mg/l in toluene, 37 mg/l in n-hexane, 16 mg/l in *n*-octanol.
pKa: 2.3
K_{ow} log P = 4.78 (25 C)

Herbicidal Uses

Propaquizafop is used for control of a wide range of annual and perennial grasses (including *Sorghum halepense, Elytrigia repens,* and *Cynodon dactylon)* in soybean, cotton, sugar beet, potatoes, peanut, peas, oilseed rape, and vegetables.

Use Precautions

Fire Hazard: Non-flammable; Liquid formulations containing organic solvents may be flammable.
Corrosiveness: Non-corrosive
Storage stability: Stable
Emergency exposure: Swallowing Do not induce vomiting. Give a glass of milk and seek medical attention.
Eye exposure: Flush with large quantities of water for at least 15 minutes. Seek medical attention.

Behavior in Plants

Symptomology: Treated grasses cease growth within 3-4 days, show chlorosis of younger plant tissues, followed by a progressive collapse of the entire plant 10-20 days later.
Absorption/translocation: Absorbed by foliage and roots and translocated throughout the plant.
Mechanism of action: Propaquizafop is a ACCase inhibitor. See fluazifop-p-butyl for more details.
HRAC/WSSA Group Designation: HRAC- A/WSSA - 1.
Metabolism in plants: Rapidly metabolized in soybean, sugar beet and cotton foliage to the free acid, followed by further metabolism to the quinoxaline oxyphenol.
Mechanism of resistance in plants: Weed biotypes resistant to other ACCase inhibitors are resistant to propaquizafop.

Behavior in Soil

Sorption: Koc 203.9-472.
Persistence: Field dissipation DT_{50} = 3 days

Toxicological Properties

Acute toxicity:
Oral LD_{50} (rats) > 5000 mg/kg, mice 3009 mg/kg ; Dermal LD_{50} > 2000 mg/kg; Inhalation LC_{50} (4 h) 2.5 mg/l air.
Chronic toxicity: (2 yr) NOEL for rats and mice 1.5 mg/kg/d, dogs 20 mg/kg/d
Teratogenicity: non-teratogenic
Reproduction: No reproductive effects observed.
Mutagenicity: non-mutagenic

Wildlife
Oral LD_{50} bobwhite quail > 6593 mg/kg b.w.;LC_{50} bluegill sunfish 0.34 mg/l (96 h); LC_{50} rainbow trout 1.2 mg/l (96 h); EC_{50} Daphnia magna > 2 mg/l (48 h); EC_{50} green algae >2.1 mg/l.
Use classification: WHO (a.i.) III

Information Sources

Primary industry sources: Syngenta

For symbol and abbreviation definitions, see page 453.

QUIZALOFOP-P

(*R*)-2-[4-[(6-chloro-2-quinoxalinyl)oxy]phenoxy]propanoic acid

Nomenclature

Common name: quizalofop-P (ANSI, BSI, ISO, WSSA) for the *R* isomer; quizalofop (ANSI, BSI, ISO, WSSA) for the racemic mixture of *R* and *S* isomers.

Manufacturers, products, and formulations

Aventis: TARGA® SUPER, 46.3 g ai/L, EC (Germany).
Du Pont: ASSURE® II, 96 g ai/L (0.8 lb ai/gal), ethyl ester, EC.
FMC: SKIRMISH®, 96 g ai/L (0.8 al ai/gal), ethyl ester, EC.
Philagro: PILTO®, 50 g ai/L, EC (France).

Other names: Quizalofop-P-ethyl. The following names all refer to quizalofop ethyl ester: ASSURE; DPX-Y6202; FBC-32197; NC 302; NCI 96683; quinofop-ethyl; quizalofop-ethyl; xylofop-ethyl; ethyl 2-[4-(6-chloro-2-quinoxalinyl-oxy)phenoxy]propionate (IUPAC); ethyl 2-[4-(6-chloro-2-quinoxalinyloxy)phenoxy]propanoate (CA).

Chemical family: Aryloxyphenoxy propionate.

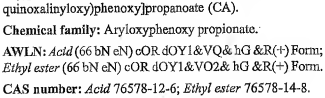
AWLN: *Acid* (66 bN eN) cOR dOY1&VQ& hG &R(+) Form; *Ethyl ester* (66 bN eN) cOR dOY1&VO2& hG &R(+) Form.

CAS number: *Acid* 76578-12-6; *Ethyl ester* 76578-14-8.

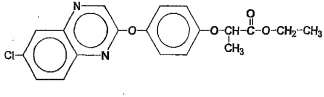
Chemical and Physical Properties

Chemical structure:

Quizalofop-P acid



Quizalofop-P ethyl ester



Molecular formula: *Acid* $C_{17}H_{13}ClN_2O_4$; *Ethyl ester* $C_{19}H_{17}ClN_2O_4$.

Molecular weight: *Acid* 344.75; *Ethyl ester* 372.81.

Description: Colorless crystals.

Density: 1.34 g/mL

Melting point: 91.7-92.1°C

Boiling point: 220°C at 0.2 mm Hg

Vapor pressure: 8.65 x 10^{-4} mPa (3 x 10^{-7} mm Hg) at 20°C

Stability: Moderately stable to UV light; Decomposes at 320°C.

Solubility

water 0.3 mg/L at 20°C
organic solvents g/100 mL at 20°C:

acetone 11	*n*-hexane 0.26
benzene 29	xylene 12.1

pK_a: *Acid* NAv; *Methyl ester* None.

K_{aw}: Not available.

Herbicidal Use

Quizalofop-P provides POST control of annual and perennial grass weeds in soybeans and non-crop areas. It can be applied POST at 35-84 g ai/ha (0.031-0.75 oz ai/A) in soybeans, POST at 84-112 g ai/ha (0.075-0.1 lb ai/A) in non-crop areas, and POST in a spray-to-wet application at 0.75% v/v for spot treatment in soybeans. Quizalofop-P controls nearly all weedy annual grasses and most perennial grass weeds including johnsongrass, bermudagrass, quackgrass, and wirestem muhly. A nonionic surfactant or oil adjuvant is required for maximum efficacy.

Use Precautions

Fire hazard: ASSURE is combustible, flash point is 61°C (142°F) (seta).

Corrosiveness: Mildly corrosive. Undiluted product may harm painted surfaces.

Storage stability: Stable for 1 yr at 45°C (113°F). Do not subject to temperatures below 0°C (32°F).

Cleaning glassware/spray equipment: Detergent wash and rinse.

Emergency exposure: Flush skin and eyes with water for at least 15 min; call a physician. If ingested, do not induce vomiting; drink large quantities of water. No specific antidote is known. Treat symptomatically.

Incompatibilities: Not available.

Behavior in Plants

Symptomology: Growth ceases soon after application with young and actively growing tissues affected first. Leaf chlorosis and eventually necrosis develop 1-3 wk after application. Leaf sheaths become brown and mushy at and just above their point of attachment to the node. Older leaves often turn purple, orange, or red before becoming necrotic.

For symbol and abbreviation definitions, see page 453.

Absorption: The ethyl ester of quizalofop (and of quizalofop-P, presumably) is readily absorbed into leaves, but not as rapidly as other aryloxyphenoxy proplonate herbicides (9). Seven d after quizalofop application, 36 to 45% could be washed off the leaf surface (7). Nevertheless, quizalofop-P appears to be rainfast 1 h after field application. The lipophilic nature of quizalofop ethyl ester may facilitate tight binding to the cuticle (7), thus further reducing the amount reaching leaf cells. Quizalofop-P ester presumably diffuses readily across the plasmalemma. Once inside the cell, the herbicide is rapidly deesterified to quizalofop acid which dissociates in the relatively alkaline cytoplasm. The anion is "trapped" inside the cell due to its inability to traverse the plasmalemma, a consequence of its negative charge and low lipophilicity. If quizalofop butyl ester is hydrolyzed outside the cell, the relatively acid environment allows a significant proportion of quizalofop acid to remain in the protonated (undissociated) form which readily diffuses across the plasmalemma and into the cell. Upon entering the alkaline cytoplasm, the acid dissociates and is trapped inside. Thus, the "ion trapping" principle facilitates a build-up of quizalofop in the symplasm.

Translocation: Quizalofop-P ethyl ester is systemic and is principally translocated in the symplasm (including the phloem). It accumulates in meristematic regions of the shoot and root, although the rate of translocation is slow (2).

Mechanism of action: As with other aryloxyphenoxy propionates and with the cyclohexanedione herbicides, quizalofop-P inhibits acetyl-CoA carboxylase (ACCase), the enzyme catalyzing the first committed step in *de novo* fatty acid synthesis (1). Inhibition of fatty acid synthesis presumably blocks the production of phospholipids used in building new membranes required for cell growth. Broadleaf species are naturally resistant to aryloxyphenoxy propionate and cyclohexanedione herbicides because of an insensitive ACCase. An alternative mechanism of action has been proposed, involving destruction of the electrochemical potential of the cell membrane, but the contribution of this hypothesis remains in question.

HRAC/ WSSA Group Designation: HRAC - A/ WSSA - 1.

Metabolism in plants: Quizalofop-P ethyl ester is hydrolyzed rapidly in plants to quizalofop-P acid. In soybeans and cotton, quizalofop acid was converted to phenol metabolites or was conjugated to glucose (3). In quackgrass, polar metabolites of quizalofop represented 26 and 48% of the absorbed herbicide 1 and 5 d after treatment, respectively, while the remainder was the ester and acid forms of quizalofop (7).

Non-herbicidal biological properties: Sublethal rates may suppress seed head development in certain grass species such as red rice and downy brome (5, 6).

Mechanism of resistance in weeds: Most quizalofop-P-resistant biotypes appear to have an ACCase that is insensitive to the herbicide. However, in diclofop-resistant rigid ryegrass from Australia, cross-resistance to a number of herbicides including quizalofop is not due to differential ACCase sensitivity (4). Rather, resistance may be due to increased herbicide metabolism or sequestration away from the site of action.

Behavior in Soil

Sorption: Quizalofop ethyl ester is moderately adsorbed on sandy loam soils and strongly adsorbed to silt loam soils.

K_{oc}: Average is 510 mL/g for quizalofop ethyl ester (8).

Transformation

Photodegradation: Half-life was 40 d on sandy loam soil.

Other degradation: Rapidly degraded by microbes under aerobic and anaerobic conditions.

Persistence: Moderate residual with an average half-life of 60 d (8). Quizalofop may suppress or control grass weeds germinating after a POST application, but degree of suppression or control is related to herbicide rate, soil type, and soil moisture.

Mobility: Thin-layer soil chromatography studies indicate very low soil mobility.

Volatilization: Not available.

Toxicological Properties

Toxicity tests were conducted with technical grade quizalofop ethyl ester unless otherwise indicated.

Acute toxicity

Quizalofop ethyl ester technical: Oral LD_{50} male rat 1670 mg/kg, female rat 1480 mg/kg, male mouse 2350 mg/kg, female mouse 2360 mg/kg; Dermal LD_{50} mouse, rat, and rabbit >5000 mg/kg; 4-h Inhal. LC_{50} rat 5.8 mg/L; Skin irrit. rabbit, none; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, mild.

ASSURE: Oral LD_{50} male rat 6600 mg/kg, female rat 5700 mg/kg; Dermal LD_{50} rabbit >5000 mg/kg; 4-h Inhal. LC_{50} rat >5 mg/L; Skin irrit. rabbit, moderate; Skin sensitiz. guinea pig, no; Eye irrit. rabbit, severe.

Subchronic toxicity

90-d dietary, rat: NOEL male 40 ppm.

Chronic toxicity

18-mo dietary, mouse: NOEL 10 ppm; liver effects.

24-mo dietary, rat: NOEL 25 ppm; not oncogenic; liver effects.

12-mo dietary, dog: NOEL 400 ppm (highest level tested).

Teratogenicity

Rat: NOEL 30 mg/kg/d; not teratogenic.

Rabbit: NOEL 30 mg/kg/d; not teratogenic.

Reproduction

Rat: NOEL 25 ppm in a 2-generation study; liver effects.

Mutagenicity

Gene mutation: Ames test, negative; CHO, negative.

For symbol and abbreviation definitions, see page 453.

Structural chromosome aberration: Unspecified test, negative; Mouse micronucleus, negative.

DNA damage/repair: SCE, negative.

Wildlife

Quizalofop ethyl ester technical: Mallard duck oral LD_{50} 2000 mg/kg; Bluegill sunfish 96-h LC_{50} 0.46-2.8 mg/L; Rainbow trout 96-h LC_{50} 10.7 mg/L.

Use classification: General Use.

Synthesis and Analytical Methods

Synthesis: Not available.

Purification of technical: Not available.

Analytical methods: Not available.

Historical: First registered in the late 1980s in soybeans and in the early 1990s in cotton. U.S. patent 4,629,493.

Information Sources

Primary industry source: Du Pont.

References

1. Burton, J. D. et al. 1989. Pestic. Biochem. Physiol. 34:76.
2. Harker and Dekker. 1988. Weed Sci. 36:545.
3. Koeppe, M. K. et al. 1990. J. Agric. Food Chem. 38:1085.
4. Powles, S. B. et al. 1990. Pages 394-406 *in* M. B. Green, H. M. LeBaron, and W. K. Moberg, eds., Managing Resistance to Agrochemicals. Am. Chem. Soc. Symp. Ser. 421, Washington, DC.
5. Richardson, J. M. et al. 1987. Weed Sci. 35:277.
6. Salzman, F. P. et al. 1988. Weed Sci. 36:800.
7. Tardif and Leroux. 1991. Weed Technol. 5:525.
8. Wauchope, R. D. et al. 1992. Rev. Environ. Contam. Toxicol. 123:1.
9. Wilhm, J. L. et al. 1986. Weed Sci. 34:333.

For symbol and abbreviation definitions, see page 453.